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Technical Report 616

Estimating Manpower, Personnel, and Training Requirements Early in the Weapon System Acquisition Process: An Application of the HARDMAN Methodology to the Army's Division Support Weapon System

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A Navy methodology designed to assess the human resource requirements of emerging weapon systems was applied to the Army's proposed Division Support Weapon System (DSWS), a self-propelled howitzer system which will eventually replace the present M109 howitzer series. The goal of the project was to determine whether or not this HARDMAN (hardware vs. manpower) methodology could be used to examine the manpower, training, and personnel demands of proposed Army weapon systems. While the project examined only one system, the results of the project indicated that Army data were reasonably good in (Continued)

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this case and the general analytic approach appeared to be useable. A second, more extensive project has been initiated to further assess the utility and generalizability of the methodology.

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Manpower and Personnel

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FOREWORD

The Army is aware of the increasing importance of training and manpower estimation throughout the life cycle process. Dollar and manpower requirements are fixed very early in system development, but their full impact is often not apparent until years later. Consequently, the Army Research Institute's Systems Research Laboratory has become involved in efforts to provide tools and procedures which will identify these human resource impacts during the early phases of weapon design. The present project, a part of ARI's larger program to evaluate the Navy's HARDMAN methodology, is an effort to learn from the Army's sister services. To the extent that parts of this Navy system are useful for Army human resource assessment, the Army will save both time and money. The Army is sincerely grateful to the Navy, in particular the HARDMAN Office (OP-112C), for its cooperation in this venture.

Edgar M. Johnson

EDGAR M. JOHNSON
Technical Director

ESTIMATING MANPOWER, PERSONNEL, AND TRAINING REQUIREMENTS EARLY IN THE WEAPON SYSTEM ACQUISITION PROCESS: AN APPLICATION OF THE HARDMAN METHODOLOGY TO THE ARMY'S DIVISION SUPPORT WEAPON SYSTEM

EXECUTIVE SUMMARY

Requirement:

During the acquisition of Army materiel systems as defined by the Life Cycle Systems Management Model (LCSMM), there is a continuing requirement for information on the personnel necessary to operate and maintain the equipment system, on the training requirements for the system, and on the costs associated with these human resource issues. Moreover, it is particularly important that these human resource demands be assessed early in the acquisition process, preferably before the major decisions on hardware design occur (at Milestone I) since such decisions tend to implicitly define the human resource demand.

Procedure:

In response to these concerns, the following project was initiated to determine what techniques and procedures are presently available which could assist the Army in assessing human resource demands in the early phases (before Milestone I) of the Weapon System Acquisition Process (WSAP). The focus was on Navy activities since the Navy's HARDMAN (Hardware vs. Manpower) Office has been addressing a similar set of problems in the Navy. The goal of the project was to determine the feasibility of applying the HARDMAN methodology developed by the Navy to Army systems.

The methodology itself is composed of six major activities: Step 1, the development of a data base to support the analytic activities (Steps 2-4); Step 2, the determination of the manpower requirements necessary to effectively operate and maintain the system; Step 3, the determination of the training resource requirements for the system; Step 4, the determination of the personnel requirements (e.g., recruiting requirements); Step 5, an integrated assessment of the cost and personnel impact of the proposed system; and Step 6, trade-off analyses (iteration of Steps 1-5). The basic analytic approach used by the methodology is comparability analysis, an approach in which data from similar existing systems and subsystems are modified and aggregated to form a description of the human resource demands of the proposed system.

The present feasibility project examined Steps 1 through 4. The testbed for the project was the Division Support Weapon System (DSWS), a self-propelled howitzer system which was in the very early part of the Conceptual Phase of the WSAP. Only one of the three vehicles in the DSWS system was examined--the self-propelled howitzer.

Findings:

The HARDMAN methodology appears to be a useful approach for the Army. Its use would enable the Army to assess the impact of human resources early in the acquisition process. Moreover, at present there appears to be no other alternative for early assessment. As for tools and data bases, it appears that most of the analytic algorithms are relatively simple and can be modified for Army use, and the necessary data, at least in this instance, existed and appeared to be of reasonable quality. Whether such data would be available for all weapon systems is a question which remains to be answered. In addition, it should be noted that several parts of the analysis still rely on expert judgment rather than explicit algorithms, and that while the approach has the face validity of its logic, it has not been empirically validated.

Utilization of Findings:

While the results of the present project were too limited in scope to provide a useful analysis of the human resource requirements of the Division Support Weapon System (DSWS), a second project has been initiated which will provide useful information. This project will examine all six steps of the methodology for all three vehicles in the DSWS scenario. The human resource information provided will be delivered to the Program Manager for Cannon Artillery Weapon Systems to be included in the logistics package for ASARC I.

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SECTION 1

EXECUTIVE SUMMARY

1.1 BACKGROUND

The HARDMAN Methodology (Hardware vs. Manpower) is a set of tools, procedures, and data bases designed to assist in the assessment of the human resource requirements of emerging weapon systems. The following is a summary of the results of the Army Research Institute's (ARI) application of this Navy methodology to the self-propelled howitzer concept of the Army's proposed Enhanced Self-Propelled Artillery Weapon System (ESPAWS)1. It is a report on a feasibility project and represents one of a number of projects being conducted by ARI's Systems Research Laboratory in support of the Army's effort to improve the consideration of human resources during the early phases of weapon system design and development.

The impetus for this research stems from several factors which are currently plaguing the Army's effort to field effective weapon systems in a timely manner: an extremely long and sometimes ineffective weapon system acquisition process; the introduction of increasingly complex weapon systems (particularly from the maintenance perspective); increasing competition from the private sector for certain skills (e.g., electronics repair skills); and the demographic trend for a decrease in the number of young men and women of service age. Perhaps the most succinct statement of the critical system development issues posed by these problems occurs in the White Paper (March 1980) written by the Army's Chief of Staff, General E. C. Meyer:

> The Army must take a broad perspective and properly integrate our acquisition plan into overall Army plans. Inherent in this concept is the identification of total requirements to support each new system.

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1. This weapon system has recently been retitled the Division Support Weapon System, (DSWS). All references to ESPAWS in this report apply to DSWS.

Mutually coordinated commitments must be obtained from both project managers and the major commands. As we field new systems, the importance of integrated logistics systems, manpower and training requirements, and maintenance needs must be recognized. Manpower requirements must define numbers, skills, grades and costs to recruit, train, and retain soldiers to man the system.

The present report focuses on one possible solution to the problem of assessing the human resource demands of weapon systems.

The project itself is the result of a cooperative effort between the U.S. Army and U.S. Navy. It represents one activity in ARI's broader effort to examine the utility of existing procedures for assessing the human resource demands of proposed weapon systems. As such, the major goal in this project, and in the continuing efforts stemming from it, is to capitalize, to the extent possible, on past DoD investments by applying Navy tools and procedures for Army applications. It represents an effort to provide the Army with a necessary analytic capability...now, i.e., with the least possible delay.

The project focused on the feasibility of using the Navy's HARDMAN Methodology, a set of procedures based on the earlier Coordinated Human Resource Technology (CHRT) work of the Air Force, to assess the human resource demands of Army systems. Both HARDMAN and CHRT are efforts to produce standardized tools and the standardized data bases to support those tools. The HARDMAN program has, in addition, integrated the output of those analytic tools with a focus on supporting the Navy's acquisition decisions.

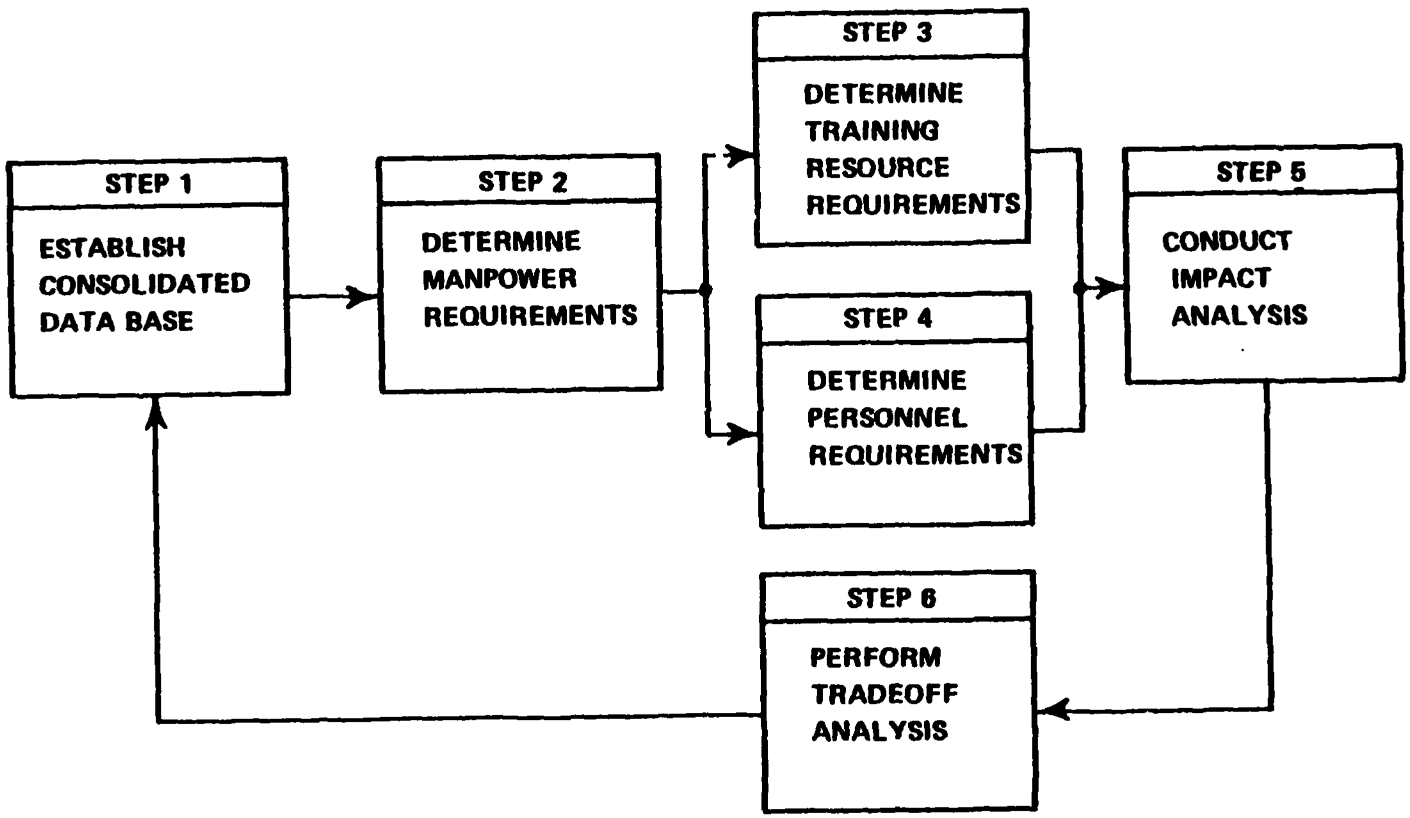
The analytic procedures used by the HARDMAN Methodology are based on three fundamental assumptions:

1) that changes in weapon technology are generally small and incremental in nature,

2) that components of equipment systems are largely refinements and reconfigurations of existing technology and equipment subsystems, and

3) that the whole system is equal to the sum of the parts.

Figure 1-1 STEPS IN METHODOLOGY



Working from these assumptions, the HARDMAN Methodology seeks to estimate the human resource demands of proposed systems by identifying existing hardware subsystems which will meet the functional requirements of the proposed system, by appropriately adjusting the human resource information associated with selected subsystems undergoing technological change, and, finally, by aggregating the subsystem demands to ascertain the total system demands. Within the engineering world this type of procedure is generally referred to as comparability analysis. The result of the application of these procedures is a set of estimates of the manpower demands for the proposed system (number of personnel slots and skill levels required for those slots), the training requirements (trainers, courses, facilities, equipment,etc.), and the personnel requirements (number of recruits who must be acquired and trained in advance to insure that the required skill levels are available to fill the personnel slots when the system is fielded). In addition, efforts are made to assess the life cycle cost of the system. The six major steps in the methodology are shown in Figure 1-1. While the Navy's HARDMAN office eventually hopes to automate all of the procedures and required data bases, at present only parts of the system are automated.

The fundamental question for the present feasibility project was "Can these procedures be modified to support Army systems?" It quickly became apparent, however, that this broader question could only be answered by addressing the more detailed questions related to the specific requirements of the methodology. These detailed questions thus became the primary focus of the study. The specific questions were:

1) Does the Army have the data necessary to support the tools and procedures of the methodology?

2) Can the existing HARDMAN tools and procedures be used to analyze the requirements of Army systems?

The system selected to be the testbed for the project was the self-propelled howitzer of the Army's Enhanced Self-Propelled Artillery Weapon System. It was selected because it represented a system which was in the very early phase (near Milestone 0) of the Weapon System Acquisition Process (WSAP), a time when design decisions have a major impact on human resource demands. The selection of the ESPAWS as the testbed would permit ARI to evaluate the utility of the tools and procedures in making early assessments of requirements.

1.2 RESULTS

Although this initial project has not provided definitive answers to the preceding questions, the results have been highly encouraging. Tentatively, the answers to the initial questions regarding the potential utility of USN HARDMAN to Army problems are as follows:

> DATA - The field maintenance data collected by the Army's Sample Data Collection system are very good for certain hardware systems; however, data of sufficient quantity and quality to support the application of the methodology does not exist for all systems. The Army's training and cost data appears to be relatively complete and of good quality. Only the Enlisted Master File (EMF) data on enlisted personnel presents any major problems. EMF data elements concerned with individual soldier training experiences are frequently not reported. The result is that career paths are difficult to determine.
>
> TOOLS - While none of the estimation tools were usable without at least minor modifications, the conceptual logic of the Reliability and Maintainability (R&M) Model appeared to be directly applicable. Moreover, it appears that this logic could be applied to project the maintenance manpower demands of virtually any Army weapon system. Other tools required substantial modifications, and the extent to which these tools can be broadly applied to Army Systems must be more thoroughly examined.

1.3 CONCLUSIONS

While the present modified HARDMAN procedures appear to provide a reasonable interim solution for the Army, the Army must take at least three major actions if it truly wishes to adequately assess human resource demands in a timely manner. First, the Army must make a commitment to the development of sound generic algorithms which can estimate

the human resource demands early in the WSAP (before Milestone I). Second, it must then identify the particular data elements required to support these algorithms and systematically collect this data. Last, both the algorithms and the procedures for handling the collected data must be effectively automated in order to provide rapid analytic responses. Without these actions, human resource assessment will too often provide too little information too late. ARI has initiated projects to address these issues, and further study is required.

1.4 FOLLOW-UP

The project report focused on the availability of data and compatibility of procedures with Army requirements. The success of the study has resulted in the initiation of a second, more rigorous analysis of the methodology. The Phase II project is a joint effort between the Army Research Institute and the Project Manager, Cannon Artillery Weapons Systems (PM-CAWS). The combined studies will make a concrete assessment of the human resource demands of the proposed configurations for the Division Support Weapon System. An analysis will be conducted for each contractor proposed configuration. The output from this project will provide the Project Manager (PM-CAWS) with information on the relative demand for human resources created by each specific contractor configuration. This will enable him to enter ASARC I with the human resource information necessary for sound trade-off decisions among configurations.

SECTION 2
ORIGINS OF THE PROJECT

2.1 BACKGROUND: COST OVERRUNS AND HUMAN RESOURCE PROBLEMS

Program costs of major system acquisitions have escalated rapidly in recent years, with actual costs outstripping early estimates. A U.S. General Accounting Office (GAO) study in 1972 showed that the actual cost of a system on the average was 90 percent higher than estimates made at the initiation of the system. Concern about these cost overruns led to reforms of the Weapon System Acquisition Process (WSAP), as formalized in Office of Management and Budget (OMB) Circular A-109. Circular A-109 called for the use of acquisition strategies which weigh the contribution that a proposed system will make to an agency's mission needs against the total resource requirements of the proposed system.

It has become clear, however, that investment costs often are overshadowed by the "costs of ownership" -- those costs incurred to effectively operate, maintain and support the system, a large proportion of which are personnel-related costs. Furthermore, factors which influence these costs are not being adequately addressed in he WSAP. The identification and assessment of the manpower, personnel, and training (MPT) resources required by a proposed design often do not occur until late in the system's development. While early attention is given to those aspects of hardware design which support mission requirements, supportability considerations are given little attention until program decisions concerning design are made. Many studies, however, have shown that it is these ea ly design decisions which drive the bulk of a system's life cycle costs. If ownership costs are to be reduced, then adequate attention to the supportability issues of operations, maintenance, and support must occur early in the WSAP, as part of the design process. This attention must include the identification of the MPT resources required for proper supportability, and an evaluation of the availability of these resources must be provided as input to the decision process.

The identification and evaluation of MPT resources is even more urgent because of the downward trend in the availability of manpower over the next 10 to 15 years for demographic reasons. During this period the demand for

skilled manpower will be increasing due to the planned introduction of new, sophisticated systems. The likely scarcity of trained manpower resources may well drive the costs associated with manning and maintaining the Armed Forces to higher absolute levels as well as increase the proportion of total life cycle costs of a system attributable to MPT factors.

Department of Defense (DoD) Directive 5000.1 and DoD Instruction 5000.2 both stipulate that supportability will be adequately addressed in the WSAP. DoDD 5000.1 mandates that supportability will be as important a design requirement as cost, schedule, and performance, and prescribes a continuous interaction between the system program office and the manpower and logistics communities. DoDI 5000.2 specifies how this increased supportability is to be addressed at the initiation of a program in the Mission Element Needs Statement (MENS), which will insure an early treatment of MPT issues.

The following sections discuss the responses of individual services to the formal guidelines provided by the Department of Defense for early considerations of supportability in general, and MPT issues in particular.

2.2 SERVICE RESPONSES

2.2.1 Air Force

At the time the need for early identification of MPT requirements and their efficient treatment in the acquisition process was becoming apparent, the Air Force's Human Resource Laboratory (AFHRL) at Wright-Patterson AFB was in the process of developing five technologies involving separate approaches with potential for meeting this need. The five technologies were:

Maintenance Manpower Modeling (MMM)
: A technique for estimating the maintenance manpower requirements for aircraft systems.

Instructional System Development (ISD)
: A method for developing and implementing an optimized training program.

Job Guide Development (JGD)

A method for developing troubleshooting and non-troubleshooting technical manuals to reduce training time and/or skills required to perform a task.

System Ownership Cost (SOC)

A systematic method for identifying major cost contributors.

Human Resources in Design Tradeoffs (HRDT)

An approach using Design Option Decision Trees (DODTs) to identify design tradeoffs and an impact analysis to quantify the effect of the tradeoffs on human resources and logistics.

The five technologies were developed and applied independently. It appeared that if the technologies could be systematically integrated and coordinated, greater speed, efficiency, and accuracy in human resource, logistics, and cost assessment could be achieved, and a mutually supportive training program and technical manual set would be developed for a given weapon system. With this in mind, a comprehensive effort was initiated in March 1977 to integrate the five technologies and evaluate the coordinated approach that emerged.

The resulting methodology, the Coordinated Human Resource Technology (CHRT), utilizes a Consolidated Data Base (CDB) that recognizes common data requirements of the several technologies and eliminates the need for individual data bases to support each. CHRT also makes possible application of each technology in earlier phases of the WSAP where the impact of system and support design decision is likely to be greatest.

AFHRL established a contract (with Dynamics Research Corporation) to conduct the study effort which produced CHRT. This effort was divided into two phases: (1) a six-month concept development phase which began in March 1977 followed by (2) an 18-month initial demonstration phase. During Phase One, the CHRT concept was developed, the five technologies were integrated, and a methodology for application was produced. Phase One also resulted in the specification of a CDB to support CHRT. During Phase Two, CHRT and the CDB were applied and demonstrated on an existing weapon system acquisition program, the Advanced Medium STOL Transport (AMST). This demonstration was used to finalize the CHRT concept and CDB content. The

integrated methodology is undergoing test and evaluation in anticipation of future application as a formal management technique for acquisition programs.

2.2.2 Navy

The HARDMAN Study and Findings. The Military Manpower/Hardware Procurement (HARDMAN) study was established by the Chief of Naval Operations (CNO) as part of the Studies and Analysis Program (CSTAP 7617T); its purpose was to propose a means of reducing cost overruns and human resource problems by insuring explicit consideration of manpower, personnel, and training requirements early in the weapon system development process. Recommendations focused on the development of modified procedures for the determination, analysis, reporting, and review of resource requirements. These procedures would fully integrate manpower, personnel, and training considerations into the acquisition process.

A number of the major findings of the study were:

- Requirements for manpower planning, and tradeoff analysis occur too late in the weapon system acquisition process and fail to address the major issues.

- Directives and instructions of the Department of Defense (DoD) and Department of the Navy (DoN) concerning the weapon system acquisition process are piecemeal and fail to reflect a systematic statement of procurement policy and guidance for managers to follow.

- Key participants in the acquisition process often lack the analytical tools to determine manpower, personnel, and training requirements early in system development and fail to insure the visibility of those requirements.

These and related findings underscored the need to develop a new methodology to assess manpower, personnel, and training requirements and to establish the procedures necessary for effective integration of that methodology into the acquisition process.

The HARDMAN Development Office. The HARDMAN Development Office was established in October 1977 to (1) develop effective ways of insuring that the tradeoff between manpower/training requirements and equipment design constraints would be given an early and comprehensive consideration, and (2) provide a means to manage and control the growth of manpower requirements associated with emerging weapon systems. Specifically, the office was organized to insure that:

- Manpower issues are properly integrated into the weapon system acquisition process.
- Hardware/manpower tradeoff capabilities are developed to support early identification of manpower requirements.
- Analytical tools and review procedures are implemented to support HARDMAN functions.
- A reporting and control system for HARDMAN functions in the weapon system acquisition process is implemented.
- HARDMAN improvements are institutionalized by the revision of procedures and the development of a HARDMAN information system.

In 1978, the HARDMAN Development Office contracted with Dynamics Research Corporation for the design of the methodology for requirements determination. Subsequently, the analytic tools and processes of the resulting methodology have been prototyped and tested on a number of weapon systems. These include the Shipboard Intermediate Range Combat System (DRC Reports No. R-267U and R-268U), the Landing Ship Dock, LSD-41 (DRC Report No. E-4932U-1), and the Undergraduate Jet Flight Training System (DRC Report No. R-359U), a study of its complete configuration (aircraft, simulators, academics and flight support, and training management system elements). The results of the LSD-41 study enabled the HARDMAN Office to influence the design of the propulsion system for the LSD-41 to compensate for an inability to recruit adequate numbers of Boiler Technicians.

Additionally, on-going validation studies for the methodology involve the Advanced Lightweight Torpedo and a new class of destroyer, the DDGX.

These and other developmental efforts are expected both to increase the methodology's capability and to refine its procedures. The continual updating and revision that this entails will be incorporated into revisions of the HARDMAN Methodology Handbook, a four-volume user's guide to the methodology, that was originally published by DRC in November 1980.

2.2.3 Army

In facing the problem of how a system's design impacts its MPT requirements, the historical context of the Army has been somewhat different from that of the Navy and the Air Force. The Army is the so-called "last service to modernize." Modernization in this context refers to both the quality and quantity of the hardware systems the Army is planning to field in the 1980s. Traditionally, the Army has been much less technology-intensive than either the Air Force or the Navy. This is changing, as the Army begins to produce and deploy major systems displaying considerable technological sophistication. These include the XM-1 Abrams Main Battle Tank, the XM-2/3 Infantry Fighting Vehicle/ Cavalry Fighting Vehicle (IFV/CFV), the Blackhawk Utility and Transport Helicopter, the Advanced Attack Helicopter, and air defense systems such as the DIVAD gun and the PATRIOT missile system. In addition, the Army is fielding improved versions of systems which were technically sophisticated for their time, such as the Pershing and HAWK Missile Systems.

Moreover, the Army is "last" in the sense that many of the first-line combat systems of the Navy and the Air Force, aircraft like F-14, F-15, F-16, and F-18, and surface combatants like the DD-963 and FFG-7 classes, were either deployed or in advanced stages of development during the mid- to late 1970's, while the Army's new systems have yet to appear. In addition to managing the simultaneous acquisition and fielding of its new systems, the Army is also developing new doctrines and force structures to insure the effective integration of these new systems into a combined arms team. This represents a considerable challenge from the standpoint of sheer numbers; a recent Army estimate put the number of systems to be fielded in the foreseeable future at 624.

While the impacts of these new systems on the MPT requirements of the Army can only be crudely estimated, if

at all, the human resource dimensions of the challenge are bound to be significant. One matter of concern is the ability of the Army, under the All Volunteer Force (AVF) program, to recruit and retain the qualified personnel it must have to operate and maintain the plethora of new systems. There is also a concern that the Army also faces a considerable qualitative divergence (measured by skills, abilities, and intelligence) between the personnel required and those personnel the AVF is likely to produce.

The problem of managing and controlling the manpower requirements of new systems was first addressed in an Army effort in strategic planning begun in the mid-1970s. This effort culminated in the issuance in 1978 of the Battlefield Development Plan (BDP) by the Army's Training and Doctrine Command (TRADOC). The BDP outlines requirements for the battlefield systems of the 1980s. It assigns specific tasks to different combat and combat support arms, and measures the ability of existing development programs to perform these tasks. By identifying shortcomings in existing programs, BDP highlights requirements for future development efforts. In this way, BDP provides a basis for the articulation of mission needs for new systems and lays the groundwork for a continuing review of mission needs through Mission Area Analyses (MAA). In addition, the BDP provides a blueprint for TRADOC to manage its efforts in training program development. With respect to MPT, the BDP recommended that the Army:

- Develop a comprehensive personnel management program that will produce the most effective individual soldier within resource constraints.
- Optimize training effectiveness in stressing combat readiness.
- Accommodate the soldier-machine interface in the early stages of new system developments.
- Identify and exploit technologies with high payoff potential and accelerate selected materiel development systems.

Army recognition of the MPT issues and their relationship to the acquisition process has been summed up succinctly and comprehensively by General E. C. Meyer, the Army's Chief of Staff, in his White Paper of March 1980:

The Army must take a broad perspective and properly integrate our acquisition plan into overall Army plans. Inherent in this concept is the identification of total requirements to support each new system. Mutually coordinated commitments must be obtained from both project managers and the major commands. As we field new systems, the importance of integrated logistics systems, manpower and training requirements, and maintenance needs must be recognized. Manpower requirements must define numbers, skills, grades, and costs to recruit, train, and retain soldiers to man the system.*

* Emphasis added

2.3 THE ARMY RESEARCH INSTITUTE'S ENHANCED SELF-PROPELLED ARTILLERY WEAPON SYSTEM (ESPAWS)[1] PROJECT

One major response to these issues has been the development by the Army Research Institute of a Manned Systems Integration Program. This program, created by the Army Research Institute for the Behavioral and Social Sciences (ARI) under the aegis of the Deputy Chief of Staff for Personnel (DCSPER), is designed to refine, integrate, and, where necessary, create, the information, tools, and management procedures required to estimate and evaluate the human resource demands of proposed weapon systems. The program's focus is on ways to influence and improve weapon system design through careful consideration of human resource factors early in the weapon system design process. The ESPAWS1 project is one piece of this program.

The ESPAWS project was established in order to examine the tools and procedures already developed by the Navy and Air Force. It represented an effort to determine what could be done now. It represented an effort to apply the existing sister service procedures to a major Army weapon system in the early phases of development.

The goals for the contractual effort were to test the feasibility of applying HARDMAN methodology to the acquisition of Army systems and to assess the generalizability and limitations of that methodology across a broad range of systems. The initial goals were to be evaluated in terms of the results of a study plan with the following objectives:

- Determine the availability in the Army of the quantity and quality of data required by the HARDMAN methodology.
- Determine the utility of using existing analytic tools-- models, techniques, processes--in the various steps of the HARDMAN methodology. These tools include those developed for use in Air Force and Navy applications, such as the Reliability,

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1 This weapon system has recently been retitled the Division Support Weapon System, (DSWS). All references to ESPAWS in this report apply to DSWS.

Maintainability, and Cost Model (RMCM) which calculates the cost impacts of changes in design parameters, and the Minimum Flow Solution (MFS) model for calculating personnel requirements. Implicit in this objective was the modification of analytic tools as required.

- Adapt, where necessary, both the data and the analytic tools to the policy and procedural requirements of the Army's acquisition and development processes.

- Subject to the above, perform the first four steps of the HARDMAN methodology to calculate a new weapon system's Manpower, Personnel and Training (MPT) Requirements. These steps are:

Step 1: Establish the Consolidated Data Base
Step 2: Determine Manpower Requirements
Step 3: Determine Training Requirements
Step 4: Determine Personnel Requirements

(A complete description of the HARDMAN methodology is contained in Section 3.)

The weapon system selected as the testbed for application was the Enhanced Self-Propelled Artillery Weapons System (ESPAWS), an integrated indirect fire support system envisioned as the successor to the Army's existing M109 series 155mm howitzers. At the time the contract was initiated, ESPAWS was in the pre-Milestone 0 phase of the weapon system acquisition process, and the Mission Area Analysis (MAA) for the system was being formulated. This project was a departure from previous efforts in that (1) the HARDMAN methodology had to be adapted to the requirements of a major ground combat weapons system, as opposed to the aircraft and seagoing applications of previous efforts, and (2) the application of the methodology was to be initiated prior to the formal approval of the Mission Element Need Statement (MENS) at Milestone 0 and was to be completed during the early part of the Conceptual Phase (the period between Milestone 0 and Milestone 1). Neither the Navy nor Air Force had ever applied the procedures so early in the acquisition cycle. (The ESPAWS System is described in more detail in Section 4).

SECTION 3
THE HARDMAN METHODOLOGY

3.1 GENERAL OVERVIEW

The HARDMAN methodology is primarily designed for front-end analysis; it determines human resource requirements, identifies high resource drivers, and provides the necessary information to conduct human resource/equipment design tradeoffs during the early phases of the WSAP. Where several competing configurations are proposed, it permits comparisons of the relative human resource demands of each.

The need for these early MPT assessments is driven by the fact that the decisions which account for 85 percent of a weapon system's life cycle costs (LCC) are made prior to full scale engineering development. The implication is that unless human resource information is entered into the decision process prior to Milestone II, it will have virtually no impact.

In general, front-end analysis, as exemplified by the HARDMAN methodology, can be characterized as:

> A process that evaluates manpower, personnel, and training (MPT) requirements during the early stages of the military systems acquisition cycle. Its purpose is to (1) determine MPT requirements under alternative system concepts and designs, and (2) estimate the impact of these MPT requirements on system effectiveness and life cycle costs. Its end-product should be the information needed to insure that effective resources (human, equipment, materiel) will be available when and as required for each system to achieve its intended contribution to military readiness and effectiveness[1].

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[1] Front-End Analysis to Aid Emerging Training Systems, Workshop Summary, HUMRRO SR-ETSD-80-3, February 1980.

In addition to its use for front-end analysis, the HARDMAN methodology is designed to serve useful functions later in the acquisition process (see Figure 3-1). During the full-scale development phase, it can be used to contribute to detailed-level logistics support analyses (LSA) and the development of such documents as the Logistics Support Analysis Record (LSAR), the Quantitative and Qualitative Personnel Requirements Information (QQPRI), the Basis of Issue Plan (BOIP), the Outline Individual and Collective Training Plan (OICTP), and the New Equipment Training Plan (NETP). After production and deployment, the methodology can be used to analyze the impact, in terms of MPT requirements, of proposed modifications to a weapon system. Again, however, its greatest value lies in its application to the early phases of the WSAP when actual design changes rather than just design "fixes" are possible.

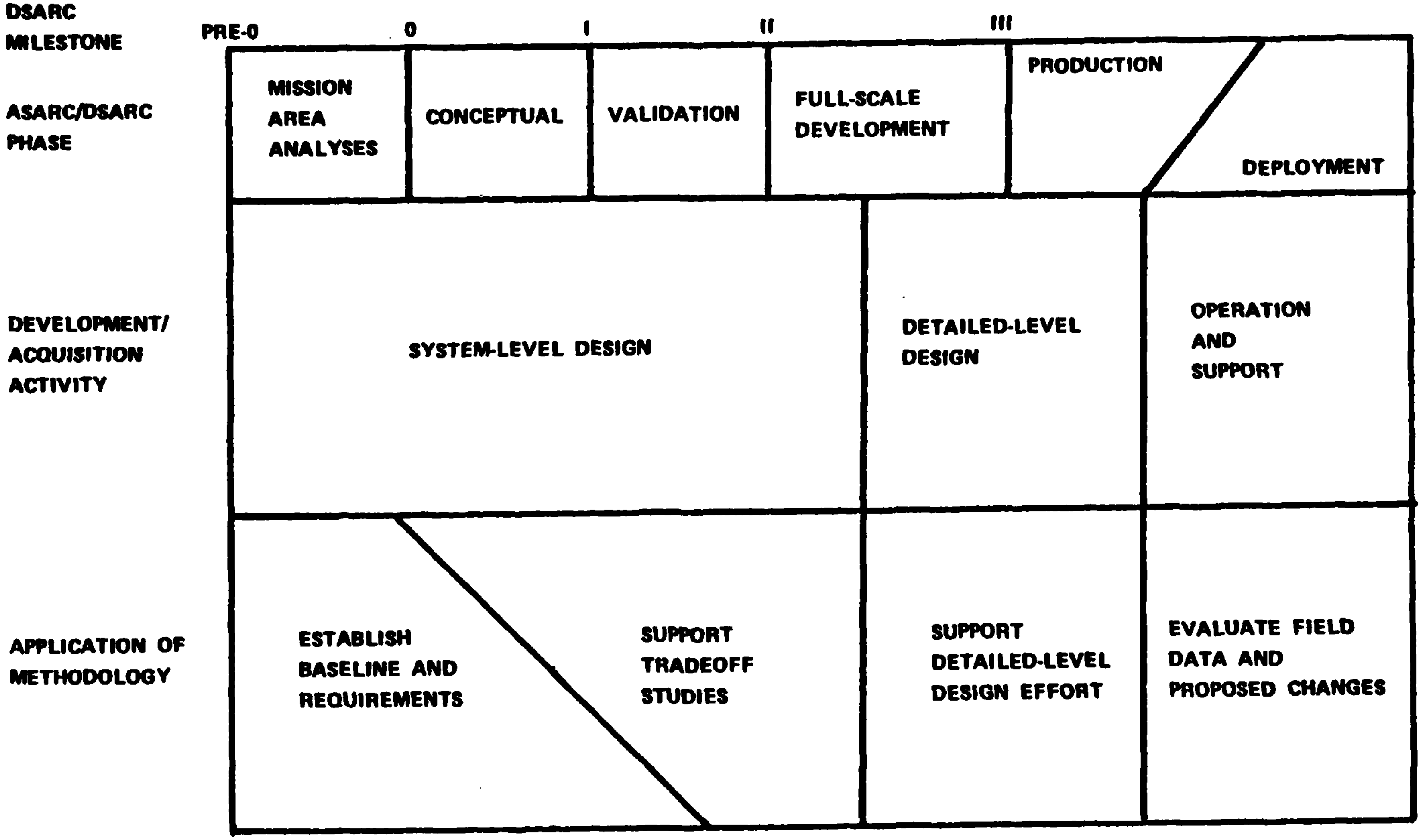
3.2 AN ACQUISITION MANAGEMENT TOOL

The HARDMAN methodology provides techniques for (1) resource requirements determination, (2) resource availability assessment, (3) impact analysis, and (4) tradeoff analyses. The resource requirements analysis determines the manpower, personnel, and training costs for proposed weapon systems in terms of numbers of persons required, skill levels required, equipments required and dollars consumed.

Resource availability assessment identifies the supply of personnel and training resources that can be expected at critical dates in the conceptual weapon system's acquisition schedule. Personnel availability analysis projects the future supply of operators, maintainers, and support personnel given current supply and expected accession and retention rates, career progression, and duty rotation rates for each Military Occupational Specialty (MOS) of interest. Training availability analysis performs the same function for critical training resource elements such as instructors. While both of these analytic tools are in a rudimentary state, the flexible format of the methodology allows incorporation of state-of-the-art supply projection methodologies as they become available.

The impact analysis matches demand to supply and identifies shortfalls in skills, new skill requirements, and high resource drivers. The tradeoff analysis then determines alternatives to lessen or shift these impacts and examines their benefits in relation to their costs. This evaluation

Figure 3-1 USE OF THE METHODOLOGY



is performed by iterating the methodology against design alternatives.

3.3 THE ANALYTIC LOGIC

The methodology is based on three fundamental assumptions:

1) That changes in weapon technology and the impacts produced by these changes are always incremental and small in nature (and can therefore be reasonably well estimated),

2) That new equipment systems are primarily refinements and reconfigurations of existing technology and equipment subsystems, and

3) That the whole system is equal to the sum of its parts.

To the extent that these assumptions are valid for a proposed system, the HARDMAN methodology is capable of providing reasonable estimates of the demands of the proposed systems. As for the actual analytic procedures, the methodology uses two important tools to accomplish its objectives. First, comparability analysis is employed to derive systematic estimates of the human resource requirements of projected systems during the earliest phases of their development. Determination of the requirements for the proposed system occurs in a three-step process.

In the first step, the fundamental functional aspects of the proposed weapon system are identified. This generic functional configuration is referred to as the notional system.

In the second step, this generic functional configuration is converted to a specific hardware configuration by assigning specific existing hardware components to each of the functional requirements. This configuration is referred to as the reference system. The components/equipments are drawn from comparable existing systems in the DoD/NATO inventory.

In the third step, the reference system is modified to reflect the impact of newer technology. This configuration,

referred to as the conceptual system, incorporates low risk technological advances likely to be extant prior to the Initial Operational Capability (IOC) date for the projected system.

To summarize, then, the basic approach to configuration definition is to move from a very general conceptual configuration to hardware specific configurations, using relatively mature data to establish the specific configurations. Estimated requirements are thus a function of relatively mature data and carefully controlled comparison between fielded and emerging technologies.

The methodology's second key analytic tool is a Consolidated Data Base (CDB) employing advanced data base management techniques. The CDB includes all of the data necessary to apply the HARDMAN methodology; this information characterizes the equipment, maintenance concept, operator and supervisor tasks, and resultant human resource requirements associated with all systems and subsystems. Consequently, all members of the program management office and the design community use identical data definitions and formats. Human factors engineers, training developers, design engineers, and manpower planners have access to and employ the same data in their individual analyses. Further, the CDB also contains a detailed audit trail which describes all internal documentation (such as worksheets, computer printouts, and programming sheets) used in the application of the methodology.

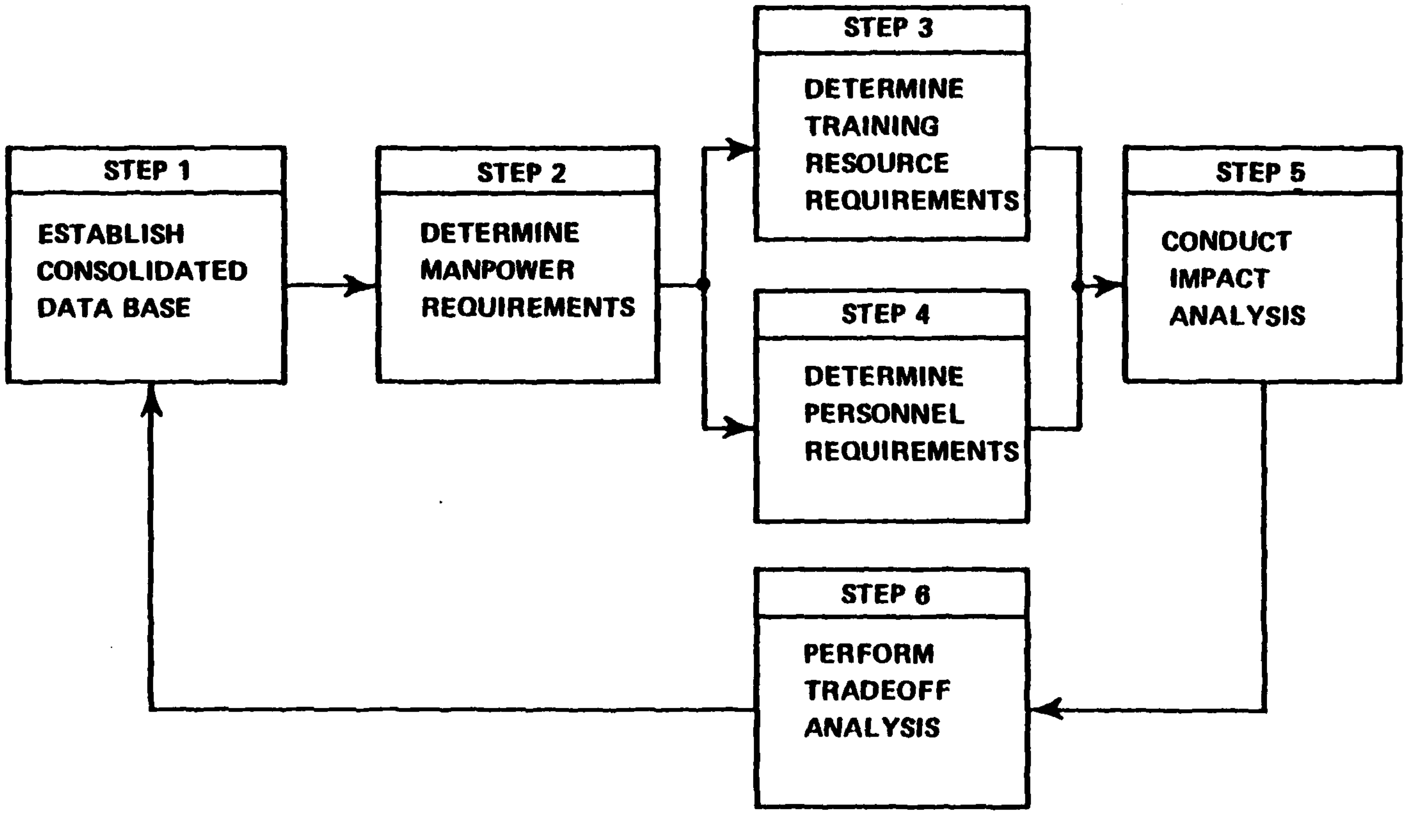
3.4 MAJOR STEPS IN THE HARDMAN METHODOLOGY

The HARDMAN methodology is composed of six major interrelated steps. The first four steps involve collection, generation, and formatting of data, while the final two involve data evaluation (see Figure 3-2). A general description of each step follows:

Step 1 - Establish a Consolidated Data Base (CDB)

During Step 1, two major functions are accomplished. First, the reference and conceptual systems are developed and the design differences are evaluated in terms of their projected impact on the reference system's operational and/or support characteristics. Second, all data required to support this and subsequent HARDMAN analyses are identified, collected,

Figure 3-2 STEPS IN METHODOLOGY



and formatted. These data include operational and support specifications for the conceptual weapon system; systems engineering data; and manpower, personnel, training, training resource, and cost data.

Step 2 - Determine Manpower Requirements

In the Manpower Requirements Analysis, systematic descriptions of the general operator and maintainer tasks/events are developed for the reference system. (Task/events describe functional activity at a more general level then the "tasks" typically used by training analysts.) Included in these task/event networks are empirically based estimates of the time, support equipment, and number and skill level of personnel required to perform each task/event. Given a mission scenario, the reference system task/event networks can be used to derive the workload for preventive, scheduled and unscheduled maintenance, operational manning, and indirect or own unit support. Further, the reference system task/event descriptions can be modified to reflect the impact of the design differences and then used to determine workload estimates for the conceptual system. These findings can then be used with the Army Manpower Authorization Criteria (MACRIT) process and/or a similar manpower determination model to estimate the number of productive personnel (operators and maintainers) and support and administrative personnel required to man the system. Additionally the reliability and maintainability analysis, used in the maintenance task/event networks, will provide a range of metrics for identifying subsystem sources of high resource demand and for comparing performance among systems.

Step 3 - Determine Training Resource Requirements

During the Training Resource Requirements Analysis, training data are collected for the reference system. These data are then modified to reflect the design differences in the conceptual design. Thus, changes are made in the operational and maintenance tasks to be performed, in individual courses (to account for the general task changes), and in course resources and cost. The impact of these changes are aggregated to determine estimates of training, training resources, and cost for the conceptual system. Additionally, a representation of the training paths for reference system personnel is developed and then modified to account for the changes in training required by the conceptual system. Consequently, the impact of conceptual changes in

training on the Army's personnel and training systems can be assessed.

Step 4 - Determine Personnel Requirements

The purpose of the Personnel Requirements Analysis is to determine the total personnel demand of the reference and conceptual systems. This total requirement consists of (1) personnel required "on-board" to operate and maintain the system, plus (2) the pipeline personnel who must be "grown" in the system to consistently meet the unit manpower requirements. This latter category of personnel is determined by constructing career paths which describe training paths, attrition rates and advancement probabilities, for the MOS's required by the reference system. These reference system career paths are then modified to reflect changes in conceptual system manning (determined in Step 2) and training (determined in Step 3). The Minimum Flow Solution model is applied to these parameters to determine the total personnel requirements of the conceptual system.

Step 5 - Conduct Impact Analysis

The Impact Analysis determines the Army's supply of those personnel and training resources required by the conceptual system and measures that supply projection against the MPT demand (determined in Steps 2 through 4). It identifies (1) new requirements for skills, training, and training resources; (2) design and other sources of high human resource demand; (3) requirements for scarce assets such as skills and training resources; and (4) high cost components of the manpower, personnel, and training requirements associated with the conceptual system. These products include many of the data elements required in current Department of Defense/Department of the Army documentation for program reviews. These products will also assist the program manager in targeting areas for human resource/ equipment design tradeoff studies.

Step 6 - Perform Tradeoff Analysis

The Tradeoff Analysis prioritizes the critical requirements (established in Step 5) according to their impact on resource availability. In keeping with this schedule, a range of potential solutions to each requirement is also determined and prioritized for analysis. The HARDMAN

methodology is then iterated to develop the most effective response to each critical resource requirement. Both the data for and the findings of these analyses are included in the CDB, thereby insuring that a complete audit trail is generated and that the most up-to-date data are available to all members of the program staff.

3.5 BENEFITS OF USING THE HARDMAN METHODOLOGY

It is expected that systematic application of the HARDMAN methodology to an emerging weapon system will provide the following benefits:

- Provide Early Estimates of MPT Requirements.

  The HARDMAN methodology determines the demand of a weapon system design in terms of manpower, personnel, training, and training resource requirements. It provides these assessments during the early phases of the weapon system acquisition process, when they can have the greatest impact on the system's emerging design.

- Provides Visibility to High Resource Drivers.

  System design characteristics, operational/support concepts and/or service policies which generate a significant demand for MPT resources are identified. This information is critical if the impacts of these requirements are to be decreased or their growth effectively managed during design maturation.

- Provides a Tradeoff Analysis Capability.

  The HARDMAN methodology is designed to conduct human resource/equipment design tradeoffs during the early phases of the WSAP. Hence, supportability considerations can be incorporated in any analysis of a system's capability and affordability.

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- Provides a Fully-Documented Audit Trail.

  A comprehensive record of all analyses and their findings is developed during each application of the methodology. Consequently, each estimate of MPT requirements associated with a system design can be systematically updated and/or verified.

- Provides Data Elements for Required Program Reports.

  The HARDMAN methodology develops many of the data elements required in program reports, as specified by Department of Defense Directive 5000.1, Department of Defense Instruction 5000.2, and Department of Defense Directive 5000.39.

- Supports Detailed Level Analysis Later in the WSAP.

  The data base and resource estimates, developed by the HARDMAN methodology during the early phases of the acquisition process, provide a solid foundation for more of the rigorous analyses conducted in the later phases (e.g., logistics support analysis, instructional systems development). Thus, estimates of MPT resource requirements are systematically updated and refined in a coherent and coordinated analysis process.

- Integrates Advanced Analysis Techniques and Current/Approved Army Analytic Tools.

  The HARDMAN methodology is a flexible format capable of effectively joining the data requirements and products both of state-of-the-art analytic processes (e.g., average value modeling, regression analysis) and of approved Army models. Consequently, all findings can be clearly related to Army standards, procedures, and practices.

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SECTION 4 - THE ESPAWS PROGRAM

4.1 OVERVIEW

The Enhanced Self-Propelled Artillery Weapons System[1] (ESPAWS) will provide the Army's combat maneuver elements with the effective fire support necessary for success on the battlefield of the 1990s. ESPAWS is intended to replace the M109 series of self-propelled howitzers, and the systems associated with it. It will become the Army's primary source of indirect fire support to armored and mechanized infantry units. ESPAWS represents one phase of a long-range planning and development effort intended to ensure the effectiveness of battlefield systems of the future.

The Battlefield Development Plan (BDP) issued by TRADOC outlines the requirements for battlefield systems of the 1980s and beyond. It does so by assigning those tasks required for successful mission accomplishment to one or more functional warfare areas of which field artillery would be a part. The result is the desired concept of an effective combined arms team. The issuance of the BDP in 1978 established the beginning of continuing Mission Area Analyses (MAA) within each warfare area.

The first phase of one of the MAA, that for Fire Support, was published in January 1980. The Phase I Fire Support MAA identified several M109 system deficiencies: range, rates of fire, position and location determination, gun laying, ammunition loading, and communications. These deficiencies will limit the ability of an M109-based fire support system to perform effectively in its role in the future.

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1 This weapon system has recently been retitled the Division Support Weapon System, (DSWS). All references to ESPAWS in this report apply to DSWS.

4.2 PROGRAM OBJECTIVES

The ultimate objective of ESPAWS is a self-propelled howitzer system suitable for autonomous operations -- doing away with vulnerable battery positions in a hostile electronic warfare environment -- and capable of offering greater responsiveness and volume of fire without an increase in personnel utilization. Howitzers are traditionally positioned in one of several battery formations -- circle, W-shaped, star, or line. The common feature of this formation is that they occupy very little ground; a typical six howitzer battery formation may be placed in the confines of a 200-meter square. When the support equipment and vehicles which accompany the howitzers are included in this area, a howitzer battery represents a fairly compact target. The damage resulting from a successful attack on such a compact target would be substantial. The ability to reduce this risk by increasing the area a battery occupies has been limited by the lack of flexible internal communications, by the necessity for manual howitzer orientation and by the dependence of each howitzer on a central fire direction center for proper cannon aiming data. These concerns were explicitly recognized in the Legal Mix V and NATO Anti-Artillery studies and summarized in the Phase I Fire Support Mission Area Analysis (MAA): "Spread battery formations offer significant survivability benefits in a hostile counterfire environment. This tactic requires individual weapon positioning and a fire unit computer system."

The MAA also indicates that ESPAWS will operate in a "target-rich" environment due to the large numbers of enemy ground combat systems. The principal task assigned to field artillery is target engagement (i.e., destroying these targets by firepower). Effective target engagement can be accomplished by an interrelationship of three factors:

- Accuracy, or the ability to hit the target;
- Lethality, the ability to kill or reduce the target when it is hit; and
- Responsiveness, achieving accuracy and lethality in a minimum amount of time.

The MAA questioned the present, M109-based system's capability in these areas, due to the communications, orientation, and fire control deficiencies cited above. Additionally, the MAA indicated that improvements in the family of 155mm ammunition and ammunition handling systems had the potential for achieving significant improvements in response times. At present, the M109 system's ammunition handling capability is labor-intensive; systems similar to the M109 (German-Italian SP-70, French GCT) have automatic ammunition loading systems. Thus an automatic ammunition loading system appears to be a necessary and appropriate feature to incorporate into ESPAWS.

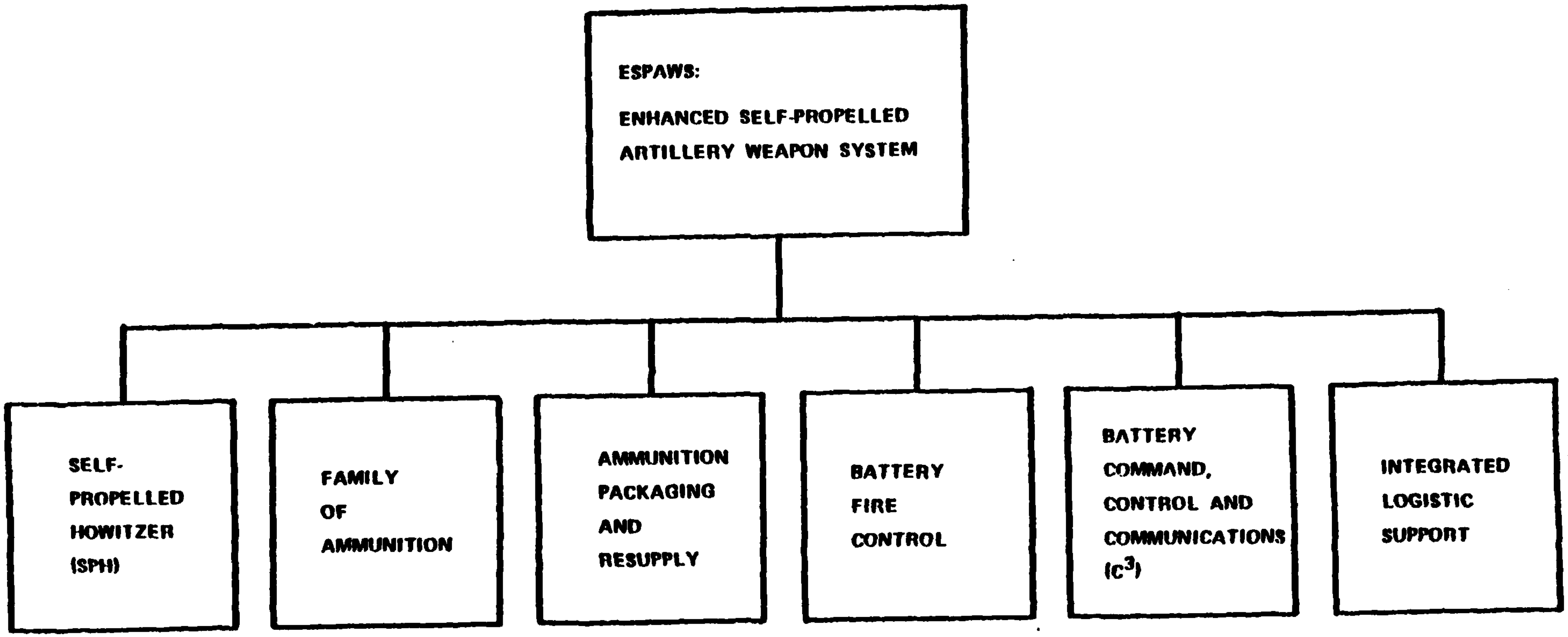
4.3 PROGRAM ELEMENTS

In order to meet the objectives of reduced vulnerability and improved fire performance, the Army requires that ESPAWS be an integrated fire support system. The ESPAWS system will consist of a new generation howitzer, improved ammunition, better ammunition handling and resupply, automated fire control and fire direction systems, advanced communications, and integrated logistics support. The six elements which make up the ESPAWS system concept are depicted in Figure 4-1. These six elements are interdependent; the design concept for one necessarily affects the concepts of the others. For example, the ammunition packaging and resupply decision concept must, for maximum efficiency, mate with the design concept for ammunition stowage on-board the self-propelled howitzer. To design both independently risks making the ammunition transfer process as time-consuming and as labor-intensive as the present system. However, these considerations are properly the subject of tradeoff analyses, and as such are beyond the scope of the present study effort, which is focused only on the ESPAWS self-propelled howitzer (SPH).

4.4 THE ESPAWS SPH

The ESPAWS SPH is the centerpiece of the ESPAWS concept. The SPH will incorporate most of the corrections to the M109 system deficiencies. These corrections will provide the improved effectiveness -- reduced vulnerability through autonomous operations and increased accuracy, lethality, and responsiveness of fires -- which is the objective of the

Figure 4-1. ESPAWS SYSTEM CONCEPT



ESPAWS program. Additionally, the SPH will have better reliability, availability, and maintainability than the present M109 series. It will achieve these objectives by incorporating existing and emerging low risk technological advances -- such as microprocessors, advanced communications, and navigation technology -- in its overall design concept and in the specific subsystems. Detailed discussion of how specific technology supports achievement of the required objectives is contained in the System Analysis subsection of Section 5, Establish the Consolidated Data Base.

The ESPAWS SPH, like its predecessor, the M109, must function effectively in two mission environments: (1) peacetime training, and (2) wartime combat. Each of these environments must be fully described in terms of those key usage metrics which affect the calculation of operator, maintainer, and support personnel workload. For example, a typical aircraft usage metric is flying hours; workload can be normalized in terms of units per flying hour. However, ESPAWS, and, indeed, most ground operations, cannot be characterized so simply. There is no one metric which will fully describe all of the operational modes inherent in the ground environment; mobility, firepower, and communications are the most common of these modes. Therefore, the ESPAWS mission environment must be described in terms of at least three metrics: (1) miles driven, to reflect mobility, (2) rounds fired, to reflect firepower, and (3) hours operated, to reflect the communications necessary for command and control.

The peacetime environment is characterized by one general mission: training. Due to the routine nature of training, it is sufficient to describe the peacetime mission environment in terms of the average values of miles, rounds, and hours over a given period of time. For ESPAWS, the annual peacetime usage is expected to resemble that of the M109, since their training missions would be similar. Table 4-1 displays their usage.

The wartime environment for ESPAWS is characterized by a multiplicity of possible missions or mission sets. These are provided via a scenario. For purposes of determining workload, the scenario must be further described in terms of the key usage metrics (i.e., quantitatively and qualitatively described). The document that provides this description is the Mission Profile/Operational Mode Summary (MP/OMS), prescribed by the RAM Rationale Annex Handbook and published by the Logistics Center at Ft. Lee, Virginia. A representative MP/OMS for ESPAWS is depicted in Table 4-2.

The MP/OMS describes the expected percentage of use for each mission, where each mission is described in terms of the key usage metrics. These mission profiles are often "built up" from detailed wargaming and other simulation efforts. In few cases do their time periods exceed several days; often the expected mission length is expressed in hours. Thus, to extrapolate into longer time periods is unrealistic to a certain degree, since combat intensity can only be sustained for so long. However, in order to form a comparison with the peacetime, *"top-down" environment*, an annual usage figure is depicted in Table 4-2.

Table 4-1
ESPAWS
EXPECTED ANNUAL PEACETIME USAGE

Miles Driven	Rounds Fired	Hours Operated
1000	750	150

Source: M109A1 Sample Data Collection.

Table 4-2. MISSION PROFILE/OPERATIONAL MODE SUMMARY[1]
FIELD ARTILLERY BRIGADE/DIVISION SUPPORT
ARMORED SELF-PROPELLED HOWITZER

OPERATIONAL MODE	MISSION PROFILE (DAILY)			USAGE	
	SUSTAINED	INTENSE	SURGE	DAILY COMPOSITE	ANNUAL (200 DAYS)
MOBILITY – MOVES –	7	12	16	10	2,000
TOTAL MILES	10.5	17	24.5	15	3,000
FIREPOWER + MISSIONS	50	88	117	72	14,400
TOTAL ROUNDS	200	375	500	300	60,000
COMMUNICATIONS – TOTAL HRS.	6	12	15	9.3[2]	1,860
% OF TIME IN THIS MISSION	50	40	10		

Movement Surfaces	Movement Speeds
Hard Surface Roads: 25%	16–37 mph
Secondary Roads: 50%	9–28 mph
Cross Country: 25%	1–19 mph

Average 35 minutes per move

NOTES:

[1]Source: TSM Cannon, Field Artillery School, Ft. Sill, OK. Numbers are average values of a more detailed mission profile/operational mode summary (MP/OMS)

[2]Active receive/transmit time in a 24-hour day

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SECTION 5 - ESTABLISH CONSOLIDATED DATA BASE

5.1 OVERVIEW

This section describes the procedures in the HARDMAN methodology for establishing a Consolidated Data Base (CDB), which serves as the single repository for information essential to the subsequent manpower, personnel, and training analyses to be conducted in the HARDMAN methodology. The CDB information is contained in hard copy documents, working papers, and other storage media such as magnetic tapes/discs. Once established, the CDB is updated throughout the acquisition phases in order to support the system design process.

This initial step in the HARDMAN methodology is divided, as shown in Figure 5-1, into the following activities:

(1) Defining the scope of the study in terms of system requirements and procurement constraints (Step 1.1);

(2) Identifying sources of information and collecting data to support the analytic process (Step 1.2);

(3) Processing and storing the data (Step 1.3);

(4) Performing system analysis to determine the equipment needed to fulfill system functional requirements by identifying a reference system of existing equipments, and defining additional technological design improvements to be incorporated in a conceptual system (Step 1.4);

(5) Reviewing the design improvements to determine their impact on the manpower, training, and personnel analyses (Methodology Steps 2, 3, and 4, respectively), and data requirements (Step 1.5); and,

(6) Indexing any changes in CDB content to provide an audit trail of the entire analytic process (Step 1.6).

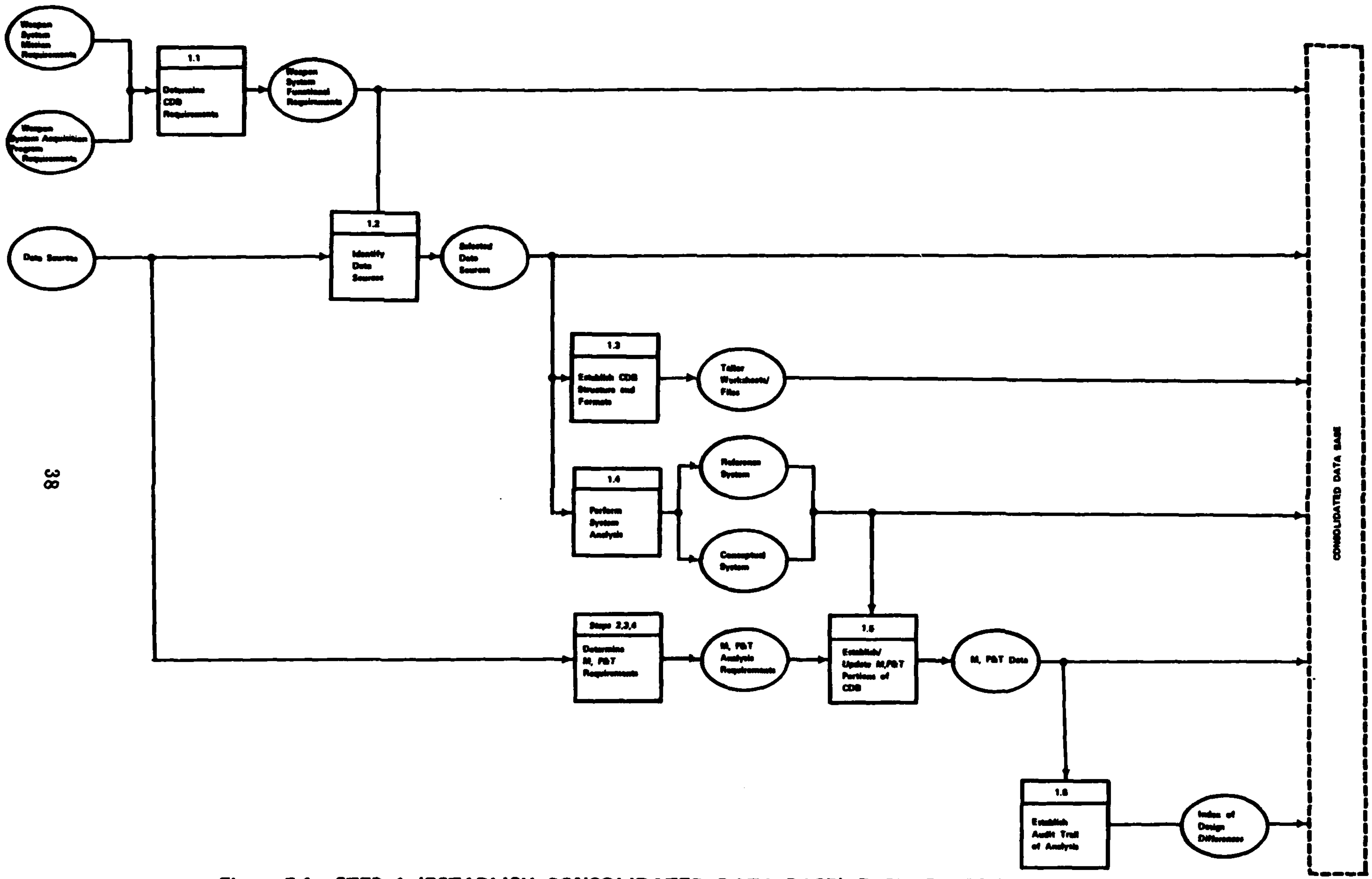


Figure 5-1 STEP 1 (ESTABLISH CONSOLIDATED DATA BASE) FLOW DIAGRAM

Each CDB step is depicted in a hierarchy diagram in Figure 5-2. Section 5.3, Application to ESPAWS, is organized to document the sequence of steps above.

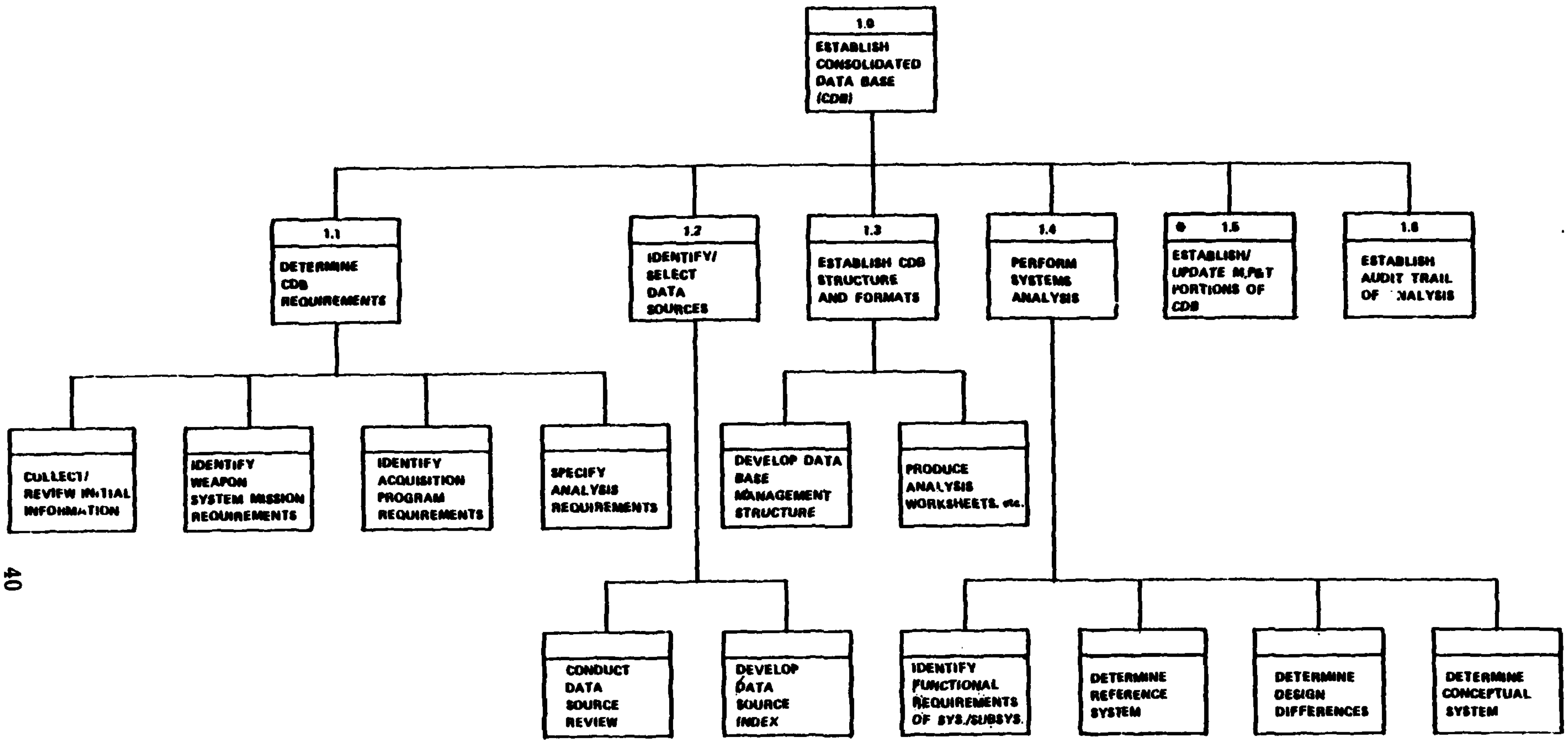
5.2 THE CDB IN THE HARDMAN METHODOLOGY

Each CDB contains the data and information files necessary to determine a weapon system's human resource requirements (manpower, personnel, and training), and to conduct tradeoff analyses, as appropriate. The data are specific to the system under study and will also include historical data from a comparable or predecessor system(s). The data elements of the CDB include not only inputs, but working data and information resulting from analysis of the system. As a result, the CDB provides the necessary data for maintaining an audit trail of each iteration of the methodology.

Before conducting manpower, personnel, and training (MPT) analyses, equipment analyses are performed to identify the equipment-related parameters, such as reliability and maintainability, which drive MPT requirements. Estimates of the equipment parameters are based on comparability analysis, (i.e., the use of historical data to compare the conceptual design with the system being replaced or with one of similar design). The capabilities, environmental conditions, and support characteristics of the system from which data are extracted must be known. These include such integrated logistics and support characteristics as maintenance/logistics concepts, support and test equipment, self-test features, special tools, training programs, special skills, and facilities.

In addition to providing the necessary equipment-related data, the CDB also provides a tracking mechanism for updating system information as the system evolves from design through development. These updates become progressively more accurate and detailed as initial estimates based on comparable historical data are replaced with operational and test data.

The principal HARDMAN processes and the general CDB data elements needed to support the methodology are depicted in Figure 5-3. The major steps of the methodology are presented in the numbered rectangles; the trapezoids represent the principal analysis processes which are conducted in several steps of the methodology. The numbers



*Step 1.5 is performed in conjunction with subsequent steps of the methodology.

Figure 5-2 STEP 1 (ESTABLISH CONSOLIDATED DATA BASE (CDB)) HIERARCHY DIAGRAM

under the trapezoids indicate those steps. For instance, referring to the first trapezoid of Figure 5-3, predecessor and reference data are collected in Steps 1.1 and 1.2 (for systems and equipment), Step 2.1 (for manpower), Step 3.1 (for training), and Step 4.1 (for personnel). The type of input and output data that make up the CDB and some of the "tools" used to process the data are shown as ovals and are grouped within the dotted blocks to illustrate that they may be part of a process and/or interrelated. The scope and timing of the particular study effort will determine whether all of the data elements will be needed for a given program. In other words, if a maintenance manpower requirements analysis is the sole focus of the study, then data for projecting the number of operators, their training requirements, and cost would not be required. Indeed, tailoring CDB requirements to preclude excessive data acquisition is an important early step in establishing the CDB.

As Figure 5-3 indicates, the CDB development process is conducted in iterative fashion with the other steps in the methodology. That is, throughout each of the subsequent steps in the methodology, data requirements are identified, collected, and placed in the CDB. Thus, revision of the CDB is a continuous process throughout the application of the methodology.

As an assessment tool, the HARDMAN outputs can be iteratively used to aid in performing sensitivity and tradeoff analyses at various levels of equipment detail during the design process. In addition, updating will include data refinement, as actual test results or larger data samples are obtained. Therefore, the accuracy of the predictions can be improved. This updating, as well as the iterative aspects of the methodology, are depicted in Figure 5-3 as a feedback line labeled "Iterate Methodology."

<u>Predecessor, Reference, and Conceptual Systems Defined:</u> During the conceptual phase of the weapon system acquisition process, the time when the methodology is typically applied, only very general functional information on the projected system is available. Therefore, to develop accurate estimates of MPT, the design-related information describing the subsystems and equipment likely to be utilized in the conceptual system must be identified. To cover the gap between the available functional information and the required design information, equipment from systems currently in the DoD/NATO inventory are identified and relevant data that will impact manpower and training on these systems are obtained and analyzed.

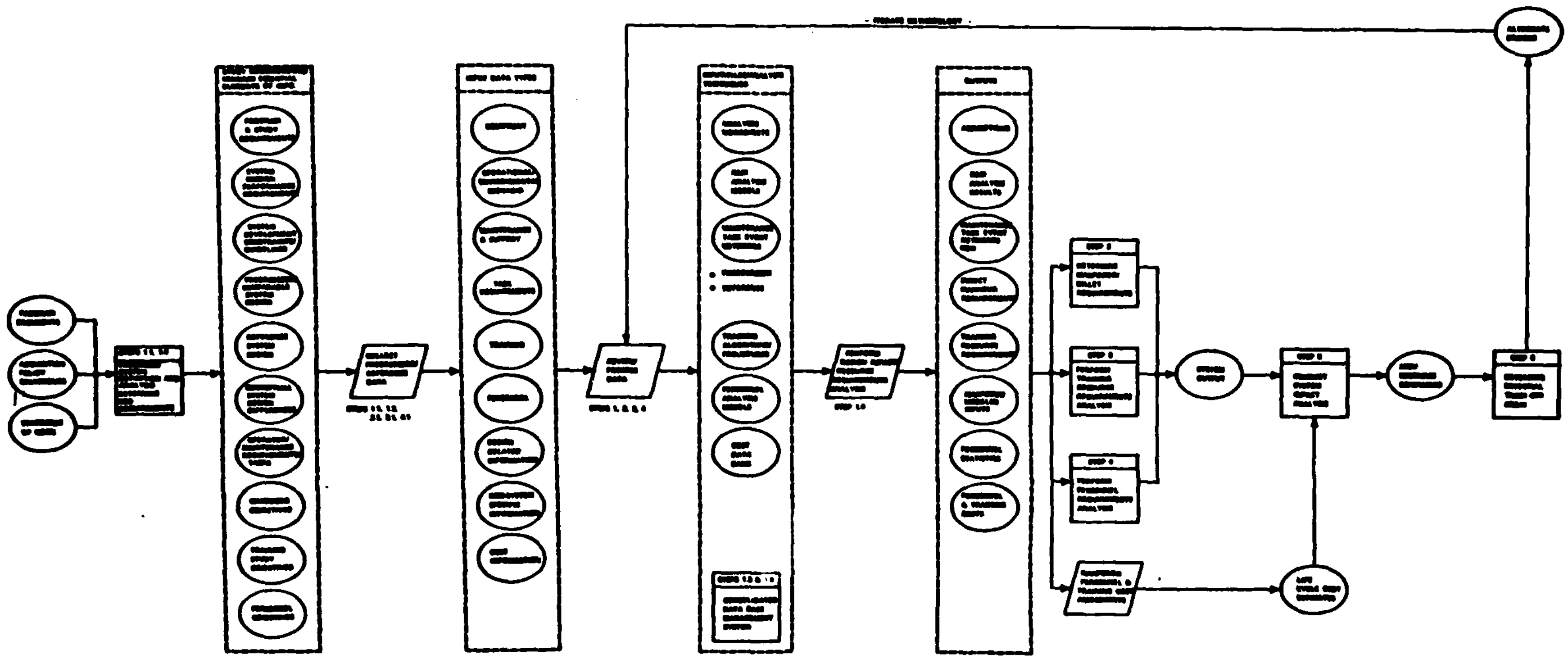


Figure 5-3 CONSOLIDATED DATA BASE DATA/TECHNIQUES USED TO SUPPORT THE HARDMAN ANALYSIS PROCESS

Development of the projected requirement for the conceptual system occurs in a two-phase process. In the first phase, a reference system consisting entirely of currently deployed equipments is determined. Should there be a predecessor system performing the mission(s) of the projected system, its subsystems become prime candidates for utilization in the reference system configuration. The next phase consists of identifying needed design improvements and determining a conceptual configuration. (In the applications of the HARDMAN methodology to Navy systems, this latter configuration is termed the "baseline" system.)

The reference system and conceptual system configurations are not intended to be the fully integrated design necessary to meet the weapon system requirements, but rather to serve as a good starting point for front-end analysis required by OMB Circular A-109; specifically, to satisfy the need for identification of potential problem areas in the manpower and training requirements. More specific definitions of the three types of systems are as follows:

Predecessor System: The predecessor system is a major system or subsystem which currently exists in DoD/NATO inventories. Replacement of this system is proposed because of excessive operation/support costs, a perceived enemy threat and/or the predecessor's mission capability has been degraded or can be augmented by technological advances.

Reference System: The reference system is a design configured to approximate a proposed major system or subsystem. The reference system meets mission/programmatic requirements specified for the proposed system in its Mission Element Need Statement (MENS) and/or Operational Requirement. The reference system is a composite of hardware and software components selected from current DoD/NATO inventories. Wherever possible, selected equipment should be mature so as to have reliability, maintainability, operating hour, and manhour data available for analysis.

Conceptual System: Like the reference system, the conceptual system is a design configured to approximate a proposed major system or subsystem. The conceptual system also meets mission/programmatic requirements specified for the proposed system in its MENS and/or Operational Requirement and is described in terms of its constituent hardware/software components. However, the conceptual system can also include modified, improved, or new design features reflecting technological advances available before the proposed system's IOC. Thus, unlike the reference

system, the conceptual system can incorporate subsystems for which only laboratory or test data are available.

The collected data includes information which characterizes the mission, equipment, maintenance concept, operator and supervisor tasks; and the resultant manpower, personnel, and training requirements associated with the systems. Initially, there may be little or no such information available for the conceptual system; however, data are extrapolated from the reference system and as additional information becomes available, it is added to the CDB.

5.3 APPLICATION TO ESPAWS

The development of the CDB followed the general sequence of steps in the methodology as depicted in Figure 5-2. Consequently, the following section is organized to follow the major substeps in the development of the CDB.

5.3.1 Determine CDB Requirements (Step 1.1)

This is the problem definition step of the CDB development process. Two things must be accomplished: (1) the weapon system under study must be defined and characterized, and (2) the scope and objectives of the study effort must be defined. In consultation with DRC, ARI selected ESPAWS for the pilot HARDMAN application effort because it (1) had a defined functional configuration (155mm howitzer), (2) was in the earliest (MAA) phase of the acquisition cycle, (3) was a major (Acquisition Category I) procurement item, and (4) was thought likely to have significant MPT effects.

The objectives of the study were as stated in Section 2, Origins of the Project. Since this was a feasibility assessment effort, the question of the appropriate scope on any particular step of the methodology was not prescribed in advance, but rather had to await preliminary determinations of whether the objectives (i.e., data availability, adaptability of analytic tools, and relevance of policies and procedures) were attainable. Thus, the scope of the effort was continually refined and definitized as the development of the CDB continued throughout the period of the study effort.

Collect and Review Initial Information. At the initiation of this study effort, ESPAWS was in the MAA phase of the acquisition cycle; hence, there was little of the program documentation which is normally available at later phases. Program initiation usually does not begin until issuance of the Mission Element Need Statement (MENS) at Milestone 0. The MENS identifies the need for a new weapons system and explains the system's general operational and support envelope. Since ESPAWS was pre-MENS, this information was not readily available. However, there were two factors which together provided the basis for beginning the application of the methodology. First, a mission need for ESPAWS had evolved during the MAA process, and a generic hardware solution or response to this mission need had been identified (155mm howitzer). Second, there were two sources which together provided the information normally found either in the MENS or in its supporting documentation. These were (1) the Phase I Fire Support Mission Area Analysis report from the U.S. Army Field Artillery Center and School at Fort Sill, Oklahoma, and (2) Contract documents for System Concept Definition for ESPAWS issued to three contractors by the U.S. Army Armaments Research and Development Command (ARRADCOM) at Picatinny Arsenal in Dover, New Jersey. These sources provided virtually the same information as is typically provided in a MENS.

Initial examination of these sources indicated that ESPAWS was composed of six elements (Figure 5-4); as a result, the scope of the study was limited to the following:

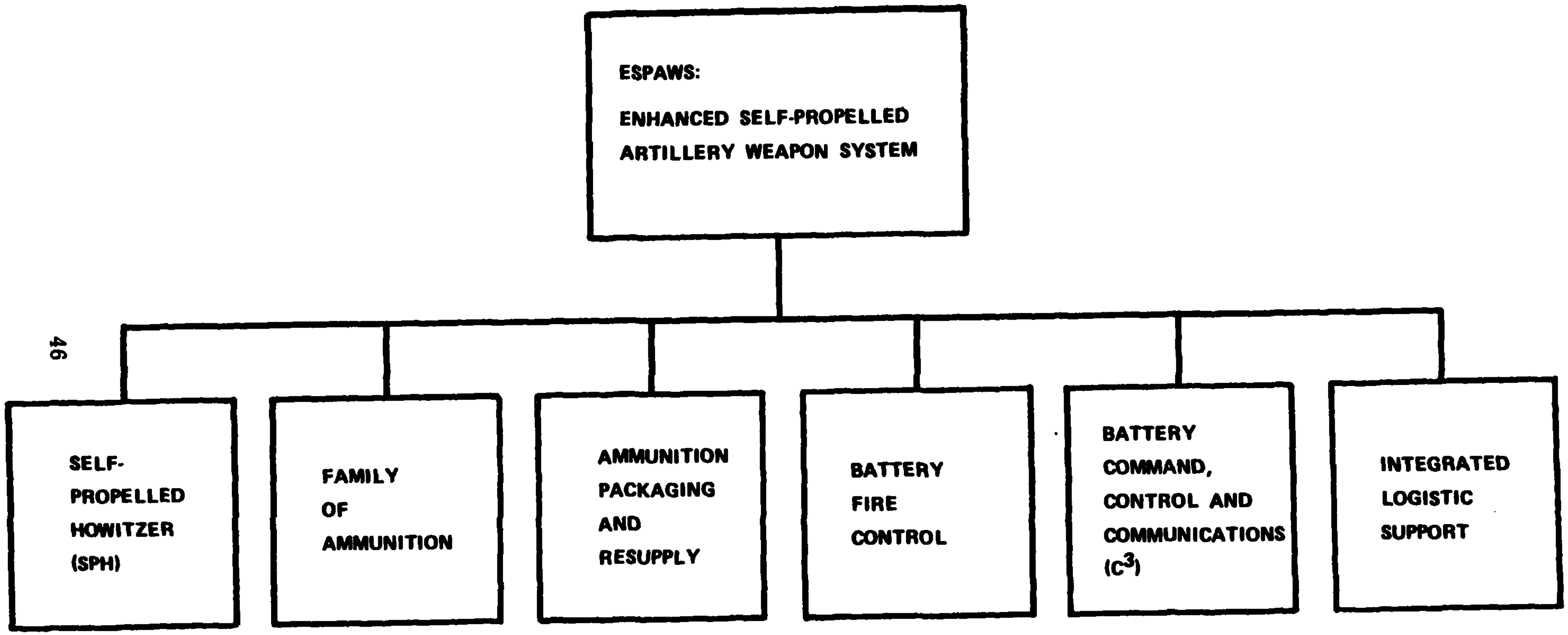
(1) Self-Propelled Howitzer (SPH) only,

(2) Direct (i.e., non-supervisory) manpower requirements for operators and maintainers, and

(3) Crew and organizational levels of maintenance (i.e., battalion level and below).

Once the scope of the study was defined, work began on collecting generalized reference library information files. These files are the compilation of the documents, papers, and other pertinent information used in the research and analysis process. They include the relevant background information known or considered to be of value to the study for which specific requirements did not have to be developed. For the ESPAWS project, the requirement for documents and information on the Army in general and its

Figure 5-4 ESPAWS SYSTEM CONCEPT



manpower, personnel, and training environments in particular, as well as background information on field artillery, was considerable. As the name "library" implies, these files were suitably arranged for ready identification and location of the material. The reference bibliography at the end of this report illustrates the scope of DRC's present library files.

Identify Weapon System Mission Requirements. Reviewing the documents collected in the previous step allowed identification of the ESPAWS mission requirements. The mission requirement definitions were then translated into specific performance objectives and required system capabilities. The solicitation for a system concept definition issued by ARRADCOM contained a preliminary mission profile for the ESPAWS system. Those subordinate mission requirements most dependent on the capabilities and performance of the proposed SPH were primary fire tasks and tactical positioning. The following extract from the solicitation amplifies these terms.

> Primary Fire Tasks: The principal contribution of the field artillery system to ground maneuver forces is its ability to execute primary fire missions. Ground force commanders must integrate all available fire support systems to defeat, suppress, or neutralize the threat array. The allocation of the artillery system to specific targets must be based on maximizing the capabilities of the artillery system to support the maneuver force. The following four general types of primary fire missions are provided to the ground force commander: (1) Target Engagement, (2) Counterfire, (3) Air Defense Suppression, and (4) Interdiction/Deep Fires. Within the total artillery system, the various subsystems are given different priorities based on their capability to effectively engage the above target types. The following table provides an example of the typical data which is applicable to the 155mm system in support of ground forces:

Primary Fire Categories	System Distribution
Target Engagement	75-80 percent
Counterfire	10-15 percent
Air Defense Suppression	5-10 percent
Interdiction/Deep Fires	1-5 percent

> Tactical Positions: In order to deliver fires in accomplishment of the primary support tasks, the field artillery system must be capable of moving with the supported ground force during both offensive and defensive operations. Within the battle area, the field artillery system must be capable of rapid and frequent movement over relatively short distances and still maintain continuous fire support operations. The relative efficiency of this movement determines the availability of fire units to engage targets in a specified operational area, to mass fires, and will increase survivability.

The mission requirements for ESPAWS may thus be broadly characterized as firepower and mobility. A third, command and control, can be logically presumed from the requirements of the first two. Thus, the artillery mission requirement embodied in the initial conceptual thinking on ESPAWS has been transformed into the "move-shoot-communicate" rubric, more familiar to practitioners of mounted combat (i.e., armor and mechanized infantry forces). This is a significant change from the previous employment of artillery, even with the gradual change over the past two decades from towed to self-propelled artillery.

Identify Acquisition Program Requirements. ESPAWS is intended to replace the M109 series of self-propelled howitzers currently deployed in the Active and Reserve forces. This information was obtained from the ARRADCOM system concept definition solicitations (to FMC Corp., Pacific Car and Foundry Corp. (PACCAR), and Norden Systems, Inc.) and a review of the Phase I Fire Support Mission Area Analysis. The Phase I MAA established that the M109 had several deficiencies which called into question the ability of an M109-based fire support system to satisfy the mission requirements as delineated above. The MAA also explicitly considered manpower as a constraint (i.e., improvements to capability should be effected without increasing the M109-based manpower levels, and should be reduced if possible).

Normally there are other sources of programmatic information available, but since ESPAWS was pre-MENS, the two data sources cited were relied upon. They were found to be sufficient to establish a functional scenario of system goals and constraints.

Review/Confirm Analysis Requirements. This is the planning step of the HARDMAN methodology. At this point the general mission requirements of firepower, mobility, and command and control were refined into the following performance objectives for the SPH:

> Increased accuracy, lethality, and responsiveness of fires, and
>
> Reduced vulnerability through autonomous operations.

These are not the only performance objectives of ESPAWS; however, it was decided to concentrate on these two because they embodied those operational characteristics which would distinguish the fire support weapon of the future from the present system.

The analytic requirements for the remainder of the application effort were obtained by tailoring the performance objectives of ESPAWS to the objectives of the study. Study objectives are defined in terms of derived output; since this was a feasibility study, no possible output of any of the four steps in the methodology which were to be applied were ruled out in advance. The result of this tailoring was a study plan which includes data collection requirements for the desired outputs that are consistent with the scope of the study. Each of these requirements is described in terms of their parameters, or characteristics essential to accomplishing the analysis. These parameters must be broken down to their values. For example, to compute maintenance manhours, parameters of reliability and maintainability are used. An example of each, respectively, would be the failure rate of a subsystem, and the time required to restore it to operation, either in Active Maintenance Time (AMT) or Maintenance Manhours (MMH).

The data elements required for analysis are formatted into lists of questions called the Minimum Essential Elements of Information, or MEEIs. Each MEEI question is limited and

specific enough to be answered by a discrete quantitative and qualitative piece of data. While this process is systematic, it is also subjective to a certain extent; the analyst developing the MEEI questions relies on past experience, knowledge of the environment, and the operational conditions in which the system functions. While the MEEIs are ideally in the form of questions, many times they can only be specified to the level of lists or groups of data; this was particularly true in the ESPAWS application. It was not known in advance how the structure of the analysis would change by applying HARDMAN to the Army; thus, specific data inputs and outputs from which question-type MEEIs could be developed were not precisely known. Based on previous Navy applications, the known general requirements of the HARDMAN methodology, overlayed with the scope of this particular application, permitted formulation of a study plan in tabular format. This is displayed in Table 5-1. Shortcomings of this approach were overcome by the orderly process of defining and collecting the necessary information to satisfy the needs of the study by relating the answers to the objectives.

5.3.2 Identify/Select Data Sources (Step 1.2)

This step involves reviewing the potential generic data sources for satisfying the study needs (i.e., the analysis requirements identified in the previous step). The criteria against which data sources are evaluated, and hence the criteria which guides the search for data sources, may be stated as follows:

> Data must be of sufficient and relevant detail to (1) satisfy the input requirements of the analytic steps of the methodology, and (2) provide outputs which satisfy the basic purposes of the methodology -- establish early MPT requirements, identify high drivers of those requirements, facilitate tradeoffs, provide an audit trail of analysis, support program report requirements, and support detailed design at later stages in the acquisition cycle.

Before beginning the search for data sources, the data categories developed for the study plan in the previous step must be updated to include information on new or state-of-

Functional Areas	Mission	Design	Manpower	Personnel	Training	Cost
Data Categories:	1. Operations – Peacetime usage – Wartime scenario 2. Maintenance Concept 3. Support Concept	1. Functional Requirements 2. Technology Information 3. RAM	1. Workload – Operator – Maintainer – Crew – Organizational 2. Other Manpower Requirements – Allowances – Constraints 3. Manpower Models – Availability – Utility	1. Current Status Information	1. Task Requirements – Operator – Maintainer 2. Skill Information 3. Course Information	1. Hardware costs 2. Personnel costs 3. Training costs

Table 5-1 STUDY PLAN

the-art equipment and/or technologies likely to be included in the conceptual weapon system. In the case of ESPAWS, particular technologies thought likely to satisfy the performance objectives and/or the functional requirements of those objectives were suggested in the ARRADCOM solicitation. The study plan was updated to include these data categories. Generic data sources known to exist were then searched for the required data categories, to surface potentially relevant specific data sources. These generic data sources included government and private libraries, particularly the Defense Technical Information Center (DTIC), the National Technical Information Service (NTIS), the Defense Logistic Studies Information Exchange (DLSIE), the Defense Manpower Documentation Center (DMDC), and the New England Research Application Center (NERAC) of the University of Connecticut. In addition, individuals within DoD and the three services were contacted for suggestions as to relevant data sources within their specific area of responsibility or within their knowledge. The cross-checking of these generic data sources to the data category requirements of the study plan provided candidate-specific data sources which had the potential to satisfy the requirements of the study. Sample data products, where possible, were obtained from these sources and reviewed for applicability to the study needs. This review entailed confirming whether the data products actually made it possible to answer the MEEI questions, where developed, in terms of being reliable and complete, as well as being applicable to ESPAWS. This process surfaced new data elements that could answer the MEEI questions or provide cross checks of existing data. The data category lists and/or MEEI questions were then updated and the process iterated to successively greater levels of detail.

The result of this process, which was performed continually over the period of the study, is a Data Sources Index. This index is a guide to the specific sources of information found to satisfy the data requirements of the analytic steps in the methodology, organized by the data categories contained in the study plan. The Data Sources Index is contained in Appendix A-1.

5.3.3 Establish CDB Structure and Formats (Step 1.3)

Develop Data Base Management Structure. Figure 5-3 provides a definitive structure for the CDB and how it conforms to its use in the methodology. Although there is considerable

overlap, the CDB is essentially structured in terms of both the type and functions of data. As data begin to be received, they will already be functionally grouped because they will be responding to a data category established in the study plan. Thus, they can be readily processed and arranged into files to support the various analytical needs of the study effort.

Data must also be classified according to type (i.e., whether it is system-specific or non-system-specific). System-specific data are those which refer to the selected reference and conceptual system notional designs. These data include operation, maintenance, and support task/event considerations, which will be formatted into task/event networks to calculate workload. Data are collected on the system and its subsystems, as well as environmental conditions and other possible constraints on the operation of the system. Non-system-specific data include Army and DoD policy and directives influencing manpower, personnel, and training requirements applicable to a variety of weapon systems. Additionally, publications documenting research conducted in these areas are reviewed, and, when possible, these data are incorporated in the CDB.

The distinction in data classification between system-specific and non-system-specific is an important one. Having an item of non-system-specific data on hand allows its use (and makes further efforts to collect it unnecessary) for additional application efforts. Proper structuring of the system-specific portion of the CDB allows distinctions to be made between the reference and the conceptual system designs, as well as identification of high drivers of MPT resources, a major purpose of the HARDMAN methodology. The remainder of this subsection discusses the structure of the (1) operational, and (2) maintenance portions of the CDB established for the ESPAWS application, which in turn were derived from the structures of the data and data bases found for the predecessor system, the M109-series howitzer. Support considerations were not addressed as they were not within the scope of the study.

(1) Operation

Operational characteristics are those which fully describe the missions of the howitzer. These characteristics determine the structure of the operation task/event networks from which workload will be calculated. Measures of these characteristics can be described as measures of mission intensity (i.e., how much did the mission require of the

equipment in terms of usage). The expected peacetime usage and wartime Mission Profile/Operational Mode Summary (MP/OMS), already displayed in Section 4, are repeated here for the convenience of the reader as Tables 5-2 and 5-3, respectively. Peacetime usage for ESPAWS is expected to average the same as that for the M109A1, as measured by the Field Artillery Sample Data Collection (SDC) (see (2) Maintenance, below, and Appendix A-2). The actual expected usage of ESPAWS (or even the M109) during wartime is highly scenario-dependent. The MP/OMS used in this study is a representative one provided by the TRADOC System Manager -- Cannon Office at the Field Artillery Center, Fort Sill, Oklahoma. It is not meant to be a statement of exactly how ESPAWS would actually be used under combat conditions; rather it is an estimate for planning purposes, and, hence, suitable for purposes of this study. In both the peacetime and wartime profiles, there are three metrics, one for each of the functional areas of the howitzer. Usage of the automotive subsystem is measured in miles driven, the armament subsystem in rounds fired, and the command and control subsystem in hours operated. (The last refers to communication or electronic hours, rather than engine hours.) Each operational mode -- sustained, intense, and surge -- can thus be described in terms of the metrics. Furthermore, the time dimensions of peacetime and wartime differ. Peacetime usage is measured on an annual basis; while in theory a year is 365 days, in terms of operating days it is substantially less. Wartime usage is estimated on a daily basis; often it is built up from detailed wargame-generated mission profiles which may be in terms of hours, or fractions of hours. The 200 days of usage in a combat year (from the RAM Rationale Annex Handbook) is a useful simplification. Since the exact number of operating days in a peacetime year could not be established, it was assumed to be 200, the same as wartime. Thus, a crude comparison could be drawn between peacetime and wartime environments normalized to the same number of operating days.

These metrics -- miles, rounds, hours, and days -- established the data structure for the operational characteristics of the field artillery brigade/division direct-support howitzer, the role the M109 presently fills, and the role ESPAWS will fill in the future.

(2) Maintenance

Characteristics of design which affect maintenance are usually described as RAM characteristics, RAM standing for

Table 5-2

ESPAWS

EXPECTED PEACETIME USAGE

Miles Driven	Rounds Fired	Hours Operated
1000	750	150

Source: M109A1 Sample Data Collection.

Table 5-3 MISSION PROFILE/OPERATIONAL MODE SUMMARY[1]
FIELD ARTILLERY BRIGADE/DIVISION SUPPORT
ARMORED SELF-PROPELLED HOWITZER

OPERATIONAL MODE	MISSION PROFILE (DAILY)			USAGE	
	SUSTAINED	INTENSE	SURGE	DAILY COMPOSITE	ANNUAL (200 DAYS)
MOBILITY – MOVES –	7	12	16	10	2,000
TOTAL MILES	10.5	17	24.5	15	3,000
FIREPOWER + MISSIONS	50	88	117	72	14,400
TOTAL ROUNDS	200	375	500	300	60,000
COMMUNICATIONS – TOTAL HRS.	6	12	15	9.3[2]	1,860
% OF TIME IN THIS MISSION	50	40	10		

Movement Surfaces	Movement Speeds
Hard Surface Roads: 25%	16–37 mph
Secondary Roads: 50%	9–28 mph
Cross Country: 25%	1–19 mph

Average 35 minutes per move

NOTES:

[1]Source: TSM Cannon, Field Artillery School, Ft. Sill, OK. Numbers are average values of a more detailed mission profile/operational mode summary (MP/OMS)

[2]Active receive/transmit time in a 24-hour day

reliability, availability, and maintainability. Reliability is the probability that an item will perform its intended function for a specified interval under stated conditions.[1] The most common measure of reliability is the Mean Time Between Failure (MTBF). Since the operation of the howitzer is also characterized in terms of miles and rounds, this measure must also be expressed as Mean Miles Between Failure (MMBF) and Mean Rounds Between Failure (MRBF). Availability is a measure of the degree to which an item is in an operable and committable state at the start of the mission, when the mission is called for at an unknown (random) point in time. The measure of availability which is most relevant to aspects of design, rather than support, is inherent availability or A_i, calculated by

$$A_i = \frac{MTBF}{MTBF + MTTR}$$

where MTBF = Mean Time Between Failures (above)
MTTR = Mean Time to Repair (see below)

Maintainability is a characteristic of design and installation which provides inherently for the item to be retained in or restored to a specified condition within a given time, when the maintenance is performed with prescribed procedures and resources. Time is the most important maintainability measure which may be applied to equipment; it is certainly the easiest to measure. There are two kinds of maintenance time. Active Maintenance Time (AMT), is the elapsed or "clock" time from the beginning of a maintenance action to its completion. Maintenance Manhours (MMH) is a measure of the resources consumed by a particular maintenance action. For example, if two people completed a maintenance action in one hour, then the AMT would be one hour, and the MMH would be two hours. The Mean Time To Repair (MTTR) is defined as the average AMT required to perform a maintenance action.

The RAM measures cited above were not the only ones with which to structure the CDB; however, they were sufficient to perform the workload calculations required by the manpower

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[1] AR702-3, Army Materiel Reliability, Availability and Maintainability (RAM).

analysis, and they were readily calculated from the maintenance data base discovered for the M109 system. This data base was part of the Field Artillery Sample Data Collection (SDC) maintained by the Armaments Materiel Readiness Command (ARRCOM) at Rock Island Arsenal, Illinois. (A more complete discussion of the Sample Data Collection system in general, and the M109 Sample Data Collection in particular, is contained in Appendix A-2.)

The SDC data had several advantages over the maintenance data systems encountered in previous applications, and over other possible sources of the same data within the Army. First, all of the data elements necessary to calculate the RAM parameters of concern were on one tape. Second, the data were collected by contractor personnel dedicated to the task, and not by unit operator or maintenance personnel. Thus, the data were more likely to accurately reflect actual field circumstances. Third, actual field data were being collected, not laboratory tests or engineering estimates. Thus it did not necessarily reflect all the prescribed maintenance, but only that which was deemed important at the maintenance level. A fourth and significant advantage over other maintenance data collection systems was that the MMH associated with each maintenance incident recorded by the SDC were fully described with the military occupational specialty (MOS) and grade of those personnel involved in performing maintenance. This advantage was significant because it allowed calculation of workload fully described in the same way; the extensive network analysis required as a bookkeeping device to meld RAM data from one source with maintenance task data from another source was thus not required. This simplified the maintenance workload determination considerably, and, hence, reduced excessive structuring of the CDB to account for it.

The SDC data also identified maintenance incidents to the specific subsystem where failure or maintenance actions occurred. It did this in two ways: through an alphabetic subsystem designation peculiar to the SDC effort, and also by using the numeric Government Functional Group Code to the 4-digit level. The latter method can specify two levels of indenture, one using the first two digits (e.g., 01 -- engine, 03 -- fuel system), and the other using all four (0302 -- fuel pump). This code, known as the GG number, is similar to the Work Unit Code (WUC) or Equipment Identification Code (EIC) employed by the Air Force and the Navy to build equipment breakdown structures. Since previous applications of HARDMAN used WUC or EIC as a cross reference index for the CDB, the GG number was used in this capacity during the ESPAWS application. A list of GG

numbers at the 2-digit level, and their corresponding subsystems, is depicted in Table 5-4.

Produce Analysis Worksheets. Normally a work package is prepared for each major system and/or subsystem in the conceptual and reference system designs. These work packages include technology information on the equipment and worksheets describing the results of any analysis. In the ESPAWS application, however, work packages were only prepared for those subsystems which were changed and/or added as a result of configuring the reference and conceptual design concepts. This allowed concentration on those areas of difference between the designs, without undergoing excessive work on the design similarities in the short time available for the study. During detailed design on the full-scale engineering development phase of the WSAP, work packages would be prepared on all subsystems.

The master design worksheets available from previous applications of the HARDMAN methodology were found to be unsuitable for the ESPAWS effort as they were deemed too aircraft-specific. New worksheets or forms were not prepared, however; rather, to be included in the work package a requirement was made that data and/or analysis had to be described explicitly, so that other analysts could take advantage of the results. No control was lost using this method, since most of the more voluminous data (i.e., maintenance and equipment breakdown structure) was contained in the computer files generated through manipulation of the SDC data. It is intended to take advantage of the "lessons-learned" from this approach by designing new supplemental and master worksheets for additional applications of HARDMAN to ESPAWS.

5.3.4 Perform Equipment/System Analysis (Step 1.4)

This step develops a key element in the HARDMAN methodology: the system design. All other steps in the analysis are dependent upon the design configuration. Figure 5-5 provides an overview diagram of the steps necessary to perform the system analysis.

<u>Identify Functional Requirements for Systems/Subsystems.</u> Developing the functional requirements for ESPAWS was accomplished by analyzing the performance objectives identified in Step 1.1, as well as considering the operational and maintenance specifications for the proposed

Table 5-4 FUNCTIONAL STRUCTURE

GOVERNMENT FUNCTIONAL GROUPING CODE (GG No.)

GG No.	Subsystem
01	Engine
03	Fuel System
04	Exhaust System
05	Cooling System
06	Electrical System
07	Transmission
08	Transfer and Final Drive Assembly
11	Rear Axle
12	Brakes
13	Track and Suspension
14	Steering Controls
15	Frame, Towing Attachments, Draw Bars
16	Shock Absorbers
18	Hull
19	Cab
20	Spade
22	Hull Miscellaneous Accessories
26	Special Tools and Test Equipment
28	Sighting and Fire Control
33	Special Purpose Kits
34	Armament, Sighting and Fire Control
43	Hydraulic System
47	Weighing and Measuring Devices
76	Fire Extinguisher System
95	General Use Standard Parts

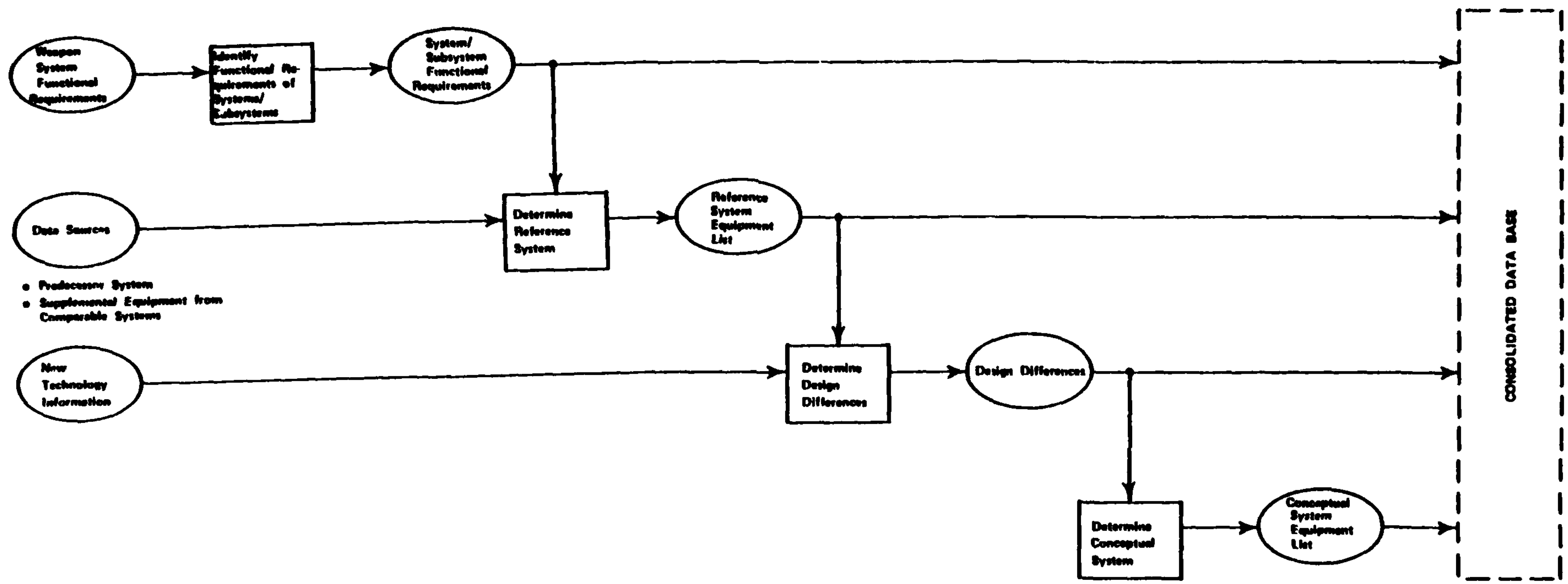


Figure 5-5 OVERVIEW OF STEP 1.4, PERFORM SYSTEM ANALYSIS

SPH. A general system/subsystem configuration was generated through engineering research; this composite established a mix of generic equipments that could functionally fulfill all requirements articulated for the conceptual system. There were six functional requirements for ESPAWS which were of particular interest, because they either significantly improved upon the existing M109 or were not present in the M109 at all. These were:

Improved ammunition handling
On-board technical fire control
Automated cannon laying
Advanced communications
On-board navigation
Improved automotive RAM

These were translated into four new configuration items:

Ammunition autoloader
Fire control computer
FM radio with data link
Attitude and heading reference system (AHRS)

A brief synopsis of the engineering analysis, which translated functional requirements into configuration items, follows:

Improved automotives: No new configuration items were required for improvements to automotive RAM characteristics. These improvements would change or modify particular equipments within the generic configuration of the predecessor M109 system, rather than the configuration itself.

Ammunition autoloader: The addition of this configuration item to the notional design concepts resulted from task analysis. Those tasks associated with converting an unprepared round of ammunition into a round chambered in the breech and ready to fire were identified using the detailed task taxonomy provided by the ARI Howitzer Crew Size model. By analyzing the time involved in accomplishing each task, it could be determined that the most significant improvement in mission response times occurred when a

notional autoloader capability was added; indeed, it was the only way that the desired response times could be achieved. This was due to the labor-intensive method of handling the current family of ammunition. There was one set of tasks which could not be translated easily into a configuration item: those associated with fuse-setting. It was also desirable to automate this capability, since it is part of the ammunition preparation process. However, this automated setting would presumably take place within the autoloader assembly. The type of fuse setter required could not be determined independent of the type of ammunition required. Hence, the autoloader assembly was assumed to contain a notional automated fuse-setting capability, since presumably the design of the autoloader, as well as the fuse-setter, would follow development of new families of ammunition and fuses as one of the elements of the overall ESPAWS concept. No other changes to components associated with the autoloader -- such as breech, recoil, or cannon servomechanisms -- were made, as potential improvements were deemed insignificant compared to the gross improvement afforded by the autoloader.

Fire Control Computer: Fire control at the howitzer and battery level consists of two functions: (1) technical fire control (conversion of raw target, location, weather, and ammunition data into aiming commands for the cannon), and (2) cannon orientation or laying (applying the aiming data to the cannon drives). Both functions are performed manually in the M109 system. Technical fire control is accomplished off-board in the battery fire direction center; cannon laying is accomplished by the crew. The ESPAWS SPH concept indicates that both these functions should be brought on-board the SPH and automated. At the early stage of the WSAP, during which this study effort was conducted, there were many alternative methods for automating these functions. One method was to adapt a single item of hardware, a fire control computer, which would accomplish both functions through individual embedded software packages. This approach was adopted because it limited the hardware analysis to a single item, yet preserved design flexibility at this early

stage of the WSAP by allowing for software growth.

FM Radio with Data Link: Truly autonomous operations require that each SPH communicate with each other and with higher authority. The M109 howitzer has no on-board radio; battery positions where each howitzer is generally within sight of another require, at most, a field telephone, and that only when fire commands cannot be transmitted by voice. In contrast, the ESPAWS SPH will have a distinct need for voice and data communications links if it is to have "shoot and-scoot" or "shoot-and-move" capabilities. Two criteria dictated the choice of an FM radio to satisfy the communications functional requirement. Tactical voice radios widely deployed at the unit level are almost invariably FM; thus, interface difficulties between artillery and other units would be minimized, hence improving command and control. The other consideration results from an analysis performed by one of the ESPAWS contractors, which indicated that the choice of a communications system could not be made independently of the choice of a land navigation system. An FM radio preserved flexibility in the choice of the land navigation system, where another choice would have closed some options.

Attitude and Heading Reference System: The key design feature for autonomous operations by each SPH is an on-board position location/orientation system. Each M109 is located on the earth and oriented towards the target by the battery executive officer using an aiming circle. Not only would an on-board system reduce the accuracy errors associated with this method (up to 21 percent of total system accuracy according to a study by the Army Human Engineering Laboratory), but also reduce the counterfire vulnerability associated with battery positions. The system selected must allow the SPH to determine its location accurately regardless of the frequency or duration of its movements. In addition, the orientation of the cannon to the earth must be measured. While a full inertial system, or independent determination of these measurements is desirable, its complexity renders it a second

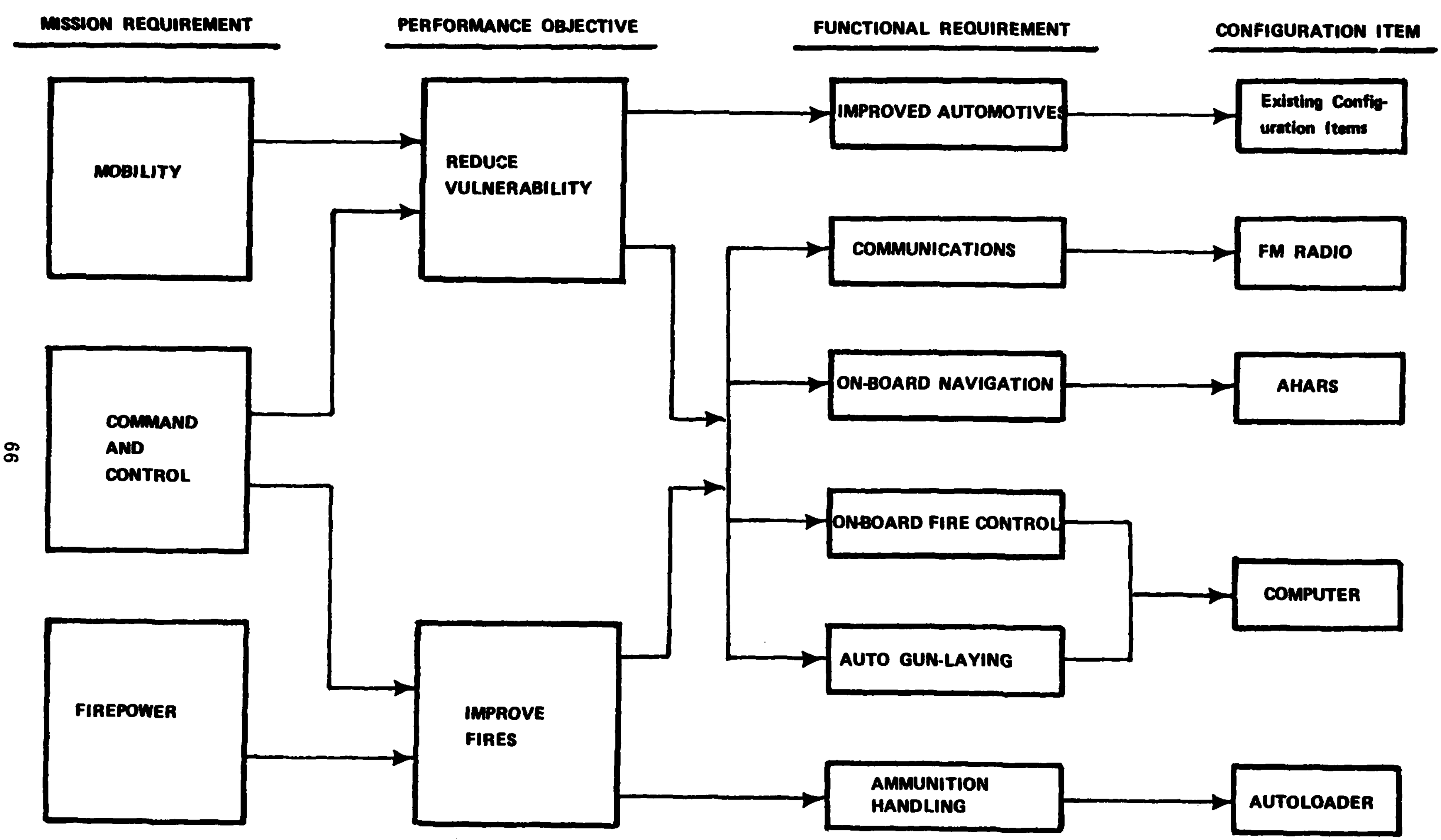
choice to an Attitude and Heading Reference System (AHRS) where the attitude of the SPH to the earth is measured directly and location is determined by reference to a known point. Tests conducted at Ft. Sill indicate that a prototype AHRS satisfies the accuracy requirements for a field artillery system.

Figure 5-6 depicts how the configuration items selected support the mission requirements for ESPAWS.

<u>Determine Reference System</u>. The reference system is a composite of the systems/subsystems, selected from the predecessor and supplemental equipments, which may be added to satisfy new functions. Normally, functions that are no longer required of the new design result in purging equipment from the predecessor system. It was decided to retain the entire predecessor M109 system as the basis for the reference system. This decision was based on the following logic:

> The functions of concern (i.e., the required enhancements in mission capability) were those which did not exist, or existed only minimally, in the M109. (Indeed, the enhancements were required specifically to overcome these deficiencies.) Thus, equipments which would satisfy the functional requirements would generally be additive, rather than replacement, in nature.
>
> Existing equipments were also retained to provide back-up capability in case of failure. This insured that the performance of the ESPAWS SPH would not fall below the M109 parameters. The notional nature of the design configuration permitted this, without regard for full integration of the existing and added equipments.
>
> In establishing the reference system, an analyst looks for differences between old and new designs which could influence MPT resources. The M109 will probably be retained in some portions of the active force inventory, as well as the reserves. The requirement for training on the M109 will not be reduced (i.e., the capability to train will be retained). Thus, the main influence on training

Figure 5-6 ANALYSIS FLOW: MISSION REQUIREMENTS TO CONFIGURATION ITEMS



resource requirements will be the addition of supplemental training topics to cover added equipments and capabilities of the conceptual system. (This assumption also greatly simplifies the Training Resource Requirements Analysis.)

Assimilating into the predecessor equipments with a supplemental equipment package designed to overcome the predecessor system deficiencies *results in the reference* system -- a notional design functionally comparable to the desired conceptual system, which could thus serve as a logical design threshold for further analysis. The criteria for selecting the equipments which made up the supplemental equipment package were that they (1) satisfied the functional requirements, and (2) have available mature RAM data. Thus, the choice of equipments for the reference system is limited to those existing DoD/NATO systems/ subsystems which meet the criteria. The list of supplemental equipments selected for the reference system is depicted in Table 5-5. No improvements to automotive RAM characteristics could be made in the reference system; no existing data were available on what the impact of these changes would be. Therefore, the planned improvements were incorporated in the conceptual design. Since GG numbers did not exist for the supplemental equipments in the predecessor, 4-digit GG numbers were assigned within the 2-digit level where the equipments were presumed to reside.

Determine Design Differences. The determination of design differences is performed in conjunction with determining the reference system (previous step) and the conceptual system (following step). The fundamental question to be addressed is whether the existing off-the-shelf technology can be presumed to be available at the time the conceptual system is required. The HARDMAN methodology requires a thorough engineering review of technologies, rather than particular items of equipment, which are projected for the future. Those technologies which appear to have impacts on MPT requirements are incorporated into the conceptual system design as *"design differences"*. The impacts of the design differences are specified as alterations to system parameters that would affect workload, both operational and maintenance. These impacts are then used to derive workload estimates for the conceptual system.

As a practical matter, it is often very difficult for the analyst to consider technology in the abstract (i.e., without also considering a particular item of equipment

Table 5-5 SUPPLEMENTAL EQUIPMENT PACKAGE — REFERENCE SYSTEM

		Equipment				
GG No.	Change No.	Configuration Item	Subsystem	Components	Source	Functional Capability
1920	19-1	Attitude and Heading Reference System (AHARS)	AN/ASN-107	Displacement Gyro CN1368 A-D Converter CV2868 Display/Control Panel	Navy (S-3A Aircraft)	Land Navigation: Position Location/ Orientation
1925	19-2	FM Radio with Data Link	AN/VRC-12(V)	Receiver-Transmitter RT-524 Receiver-Transmitter RT-246 Receiver, R-442 Antenna Subsystem AS-1729	Army (Multiple Deployments)	Communications
1930	19-3	Ammunition Autoloader	MK42 Mod 10 5"/54 Gun Mount (Modified Configuration)	Feed System Ready Ammunition Magazine	Navy (Multiple Deployments)	Ammunition Handling
2810	28-1	Fire Control Computer	AN/ASQ-155	Computer Control C9635 A-D/D-A Converter CV3163 Display/Control Panel	Navy (A-6E Aircraft)	Technical Fire Control Automated Cannon Laying

which embodies the technology). The question of whether determination of design differences properly precedes or follows determination of the conceptual system equipments is dependent on the quantity and quality of data available on new technology and/or equipment. Usually data exist either on technology in the abstract (in which case the impact of the design differences must be extrapolated from data on reference system equipments) or on equipment (in which case the impacts are explicitly estimated in the form of new operational or maintenance parameter values, but the design differences must be determined through engineering research). In the ESPAWS application, there were cases of both, but it was found that the latter situation was more prevalent.

The reasons for this are unknown, but a hypothesis can be advanced. In the ESPAWS case, the significant introduction of technology into the self-propelled howitzer takes place in the reference system, rather than in the conceptual system. What constitutes "new" technology, however, is only new in the sense that it is innovative in its application to the SPH, rather than being innovative per se. The equipments in the reference system which embody this technology are, by and large, not technologically current in the areas for which they were originally designed (e.g., the AN/ASQ-155 computer). Thus, there were likely to be more state-of-the art equipments available for inclusion into the conceptual system (e.g., the AN/AYK-14 Computer) rather than examples of technology which awaited exploitation in a particular item of equipment.

The design differences which were determined are depicted in Table 5-6. They are included in this section as it follows the HARDMAN methodology as designed. The reader should keep in mind the discussion of the order in which these design differences were arrived at. The next section briefly outlines the selection of equipments for the conceptual system.

Determine Conceptual System. The conceptual system is a notional design that has evolved through the analysis of existing equipment and technology. The conceptual system is predicated on selected reference equipments, their design enhanced by a new technology, and supplemental advanced equipments reflecting logical design progressions. In the case of ESPAWS, improving the RAM characteristics of selected automotive subsystems, and improving the ammunition autoloader represented cases of technology enhancements. Advanced equipments were introduced to the land navigation and fire control computer subsystems. One system, the FM

Table 5-6 CONCEPTUAL SYSTEM DESIGN DIFFERENCES

GG No.	Change No.	System	Design Change
01	NO1-1	Engine	1. Oil cooling redesign
	NO1-2	Engine	2. Standard Test Equipment/Internal Combustion Engine (STE/ICE)
03	NO3-1	Fuel	1. Waterproof air cleaner blower
05	NO5-1	Cooling	1. Increase capacity
	NO5-2		2. Increase radiator surface area
	NO5-3		3. Relocate fan
06	NO6-1	Electrical	1. Starter cut-off switch
	NO6-2		2. Improve ventilating blower
	NO6-3		3. Improve neutral safety switch
	NO6-4		4. Redesign/relocate components
13	N13-1	Track and suspension	1. Redesign road wheel seals
19	N19-1	AHARS	1. KHS 2100
		FM Radio	2. No change
	N19-3	Ammunition Autoloader	3. Improved electronics, BITE, modular design
28	N28-1	Fire Control Computer	1. AN/AYK-14

radio, remained unchanged since its logical successor, now in development, may not be available by the deployment date required for ESPAWS. However, this subsystem, as indeed the entire conceptual system equipment configuration, possesses the functional capabilities required of the ESPAWS. The complete equipment lists for the predecessor M109, and the notional designs of the reference and conceptual systems, are contained in Appendix A-3.

5.3.5 Establish Manpower, Personnel, and Training Portions of the CDB (Step 1.5)

The findings generated by the manpower, personnel, and training requirements analyses were incorporated into the CDB. Thus, these data were updated and became available to the other disciplines.

5.3.6 Establish Audit Trail of Analysis (Step 1.6)

Each member of the analysis team provided data inputs supporting individual analysis requirements, as well as updates to these data. Regardless of whether these updates were corrections, modifications, or additions, they were properly annotated and dated to avoid the errors likely to occur when various analysts use the same files (see Produce Analysis Worksheets). This systematic procedure insured that a proper audit trail was established for all of the analysis steps.

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SECTION 6
DETERMINE MANPOWER REQUIREMENTS

6.1 OVERVIEW

Step 2 of the HARDMAN methodology, Manpower Requirements Analysis, developed estimates of manpower requirements for the emerging ESPAWS design. This was accomplished by application of the basic process outlined in Section 6.2, after necessary refinement and tailoring to meet Army and ESPAWS requirements. These modifications to HARDMAN were dictated by the fact that the methodology, while system generic, used tools and data bases which in many ways were service specific (Navy).

The necessary modifications and the specific application of the modified HARDMAN manpower requirements analysis to ESPAWS are discussed in detail in Section 6.3, which follows the general analysis discussion in Section 6.2.

The end result of this step was a projection of ESPAWS crew and organizational level manpower requirements for use by the training and personnel analyses steps of the HARDMAN methodology.

6.2 MANPOWER REQUIREMENTS ANALYSIS IN THE HARDMAN METHODOLOGY

As developed for the Navy, the Manpower Requirements Analysis provides estimates of the manpower levels associated with an emerging weapon system design. It identifies the specialty codes of system operators, maintainers, and support personnel. The analysis also facilitates the derivation of a cost estimate for the manpower requirements.

First, workload categories which are consistent with current and available workload data are selected and defined. These categories are also consistent with service-approved definitions, and they update and refine workload categories established in the study plan. Raw workload data are collected using approved service techniques. These data are likely to come from several sources: (1) data already

collected and residing in the CDB, such as mission and support scenarios; (2) reliability, maintainability, lab and test data; (3) task and job analyses; and (4) manpower factors, standards, and estimating relationships. The workload data are refined, normalized (put on the same comparative basis), and formatted into reference system task/event networks from which workload is calculated. Engineering analysis of design differences and emerging low risk technologies is conducted to derive perturbation values, which are applied to the reference system networks to develop the conceptual system networks. The resulting workload estimates for both the reference and conceptual systems are then run through an appropriate manpower requirements determination model, usually service approved, to determine manpower requirements.

The outputs of this analysis are comparative metrics, such as Mean Time Between Maintenance Actions, and quantitative and qualitative manpower requirements. These outputs are also used in the Training Resource Requirements Analysis, Impact Analysis, and Tradeoff Analysis.

6.3 APPLICATION TO ESPAWS

6.3.1 Methodology Refinement and Modification

As previously stated, the HARDMAN approach outlined in Section 6.2 is Navy specific and required modification for Army use. The Navy currently has relatively complete coverage in terms of manpower methodology and models across the full spectrum of workload categories. Many areas, however, lack mature and/or reliable historical workload data. The HARDMAN methodology, as developed for the Navy, is thus slanted toward the detailed development of workload data.

In the Army's case, the situation is reversed. Workload data, at least for maintenance, were readily available from the Sample Data Collection System. These data were sufficient in terms of accuracy and maturity to support the ESPAWS study.

There was a lack, however, of an approved model with the sophistication necessary to integrate these data with operator and support workload data into a composite manpower

requirement. Much of the effort in the Manpower Requirements Analysis of ESPAWS was devoted to developing a methodology which would overcome this lack of a sophisticated estimation model.

What was desired was a consistent approach to manpower requirements determination, one that would carry a weapon system throughout its entire life cycle. This need was satisfied by the generation of a standard computational algorithm that is responsive only to changes in equipment or functional requirements (specific values of standard input variables). The method for calculating manpower requirements remains unchanged.

It was also important to incorporate existing methodology, constraints, and factors into this new methodological approach. For this reason, the current Army methodology, Table of Organization and Equipment (TOE) Manpower Authorization Criteria (MACRIT) from Army Regulation 570-2, was thoroughly analyzed to determine its adaptability. The results of this analysis indicated that while MACRIT could not be directly applied to ESPAWS without several major modifications, it could be used as a foundation. If these modifications are to be clarified, the MACRIT process must first be summarized.

Manpower authorization criteria are defined as the number of direct workers required to effectively perform a specified work activity. The MACRIT process outlined in AR 570-2 provides justification for approximately 60 percent of total Army manpower authorizations. It does not justify authorization for direct combat positions, such as infantry or artillery. For logistics, administrative, and service positions, however, MACRIT provides almost 100 percent coverage. MACRIT can be divided into three general sections:

> Planning Factors: These are assumptions, allowances, and constraints that are used to derive annual productive manhours for the various services or mission areas.
>
> Position Requirements: These are authorized positions made on an organizational or other basis, but not directly attributable to workload (e.g., one first sergeant per company, two mechanics for every four vehicles).

Requirement Standards: These are manpower requirements which are calculated in a basic equation that relates workload to productive manhours.

Figure 6-1 displays the basic MACRIT equation, both at a general level and with the specific types of data element inputs required by AR 570-2. The modifications to MACRIT procedures made for the ESPAWS project changed only the specific values of the data element inputs; the equation itself was not altered.

The accuracy and appropriateness of current workload data and productive time allowances, as well as the lack of an audit trail for these inputs, have been recognized as problems by the Army. Efforts are underway to establish a more reliable system.

To deal with these problems two basic modifications were made to the input data elements in developing manpower requirements for ESPAWS. The modifications involved: (1) assumptions concerning minimum essential mission capabilities to allow derivation of operator workload; and (2) the development of an alternative value for the productive capacity data element in the MACRIT equation.

The derivation of operator workload requires the assessment of minimum essential mission capabilities based upon an analysis of the mission environment in which ESPAWS would operate. This environment was represented by the Mission Profile/Operational Mode Summary (MP/OMS) (See Sections 4 and 5). Four distinct capabilities were found to be required of the system under battlefield conditions:

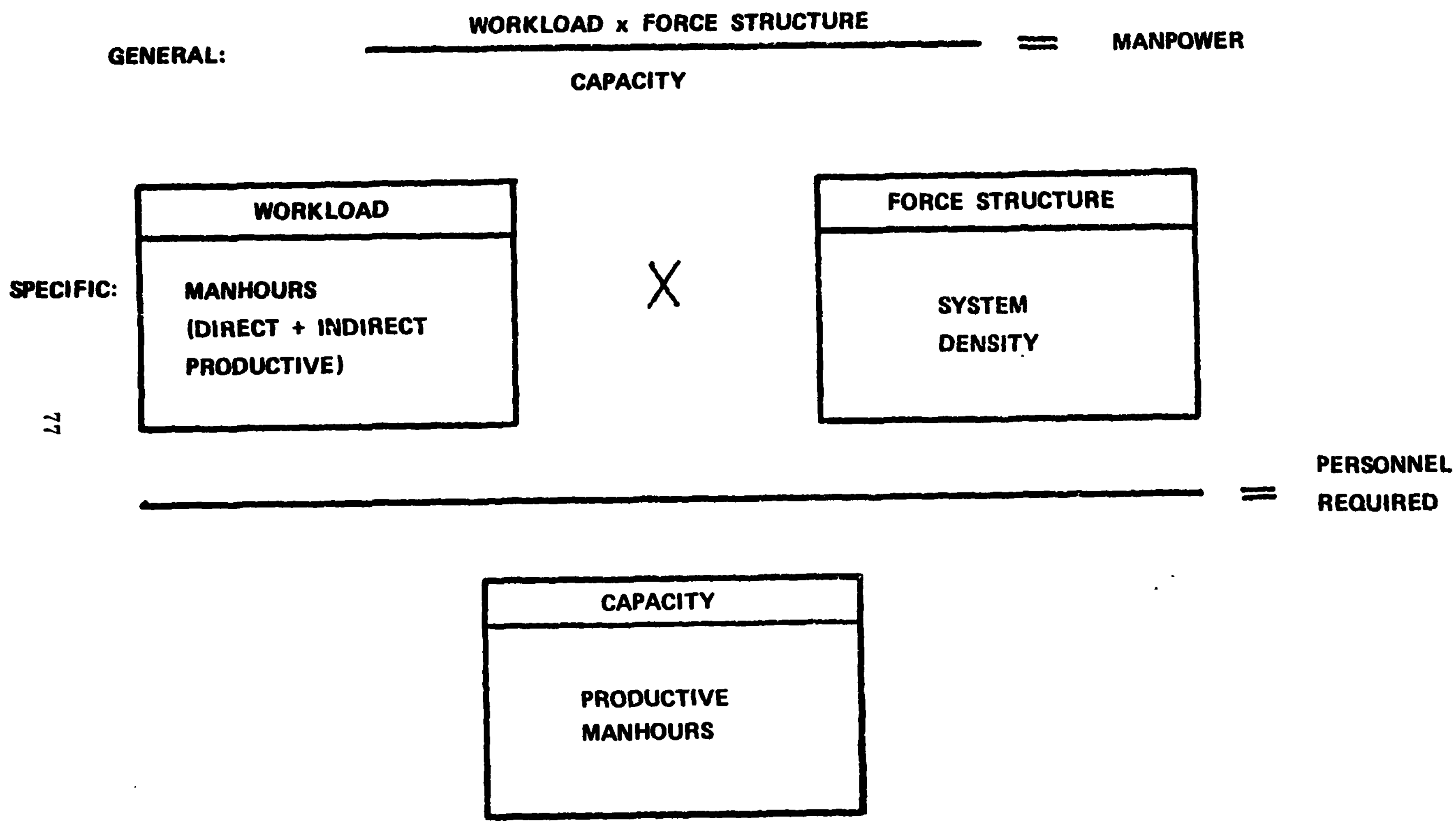
1. Moving as required under battlefield conditions (tactical positioning).

2. Performing primary fire tasks.

3. Performing all maintenance for which the crew is responsible.

4. Maintaining continuous communications.

Figure 6-1 MACRIT CALCULATION



Some of these capabilities are mutually exclusive (firing precludes movement, and to some degree, maintenance), while others overlap (communications must be maintained at all times). Trying to develop workload for each capability separately is difficult at best. For firing tasks in particular, estimating the time involved in performing fire missions is subjective, scenario-dependent, and extremely complex. However, for firing situations, the following simplifying assumption was developed:

> Accurate projections of time spent performing primary fire tasks are unnecessary if the capability (i.e., sufficient manpower) to perform these tasks effectively is always present.

A further assumption was that allowances for security, kitchen police, and work details would not be considered as required mission capabilities. While these activities may be necessary, they are not essential to the effective operation of the SPH per se, but rather to the effective operation of the organization to which the SPH is assigned. This workload then should not be counted as an allowance attributable to the SPH. The casualty allowance was also excluded. This is really a personnel requirement (i.e., overhead required to fill space requirements generated by expected casualties). (It should be noted here that the Minimum Flow Solution (MFS) model used in Section 7 will provide personnel requirements necessary to fill manpower requirements.) The assumption set, thus developed, allowed computation of minimum essential manpower requirements for each mission capability. These are discussed below under Crew Manpower Requirements.

The second modification to the MACRIT equation involved developing an alternative value to the productive capacity figure. MACRIT presently uses Annual Productive Manhours, which can vary from 2500 to 3300 per individual, depending on assumptions about unit movement. (Unit movement is the deployment of entire units, and is over and above the requirement for tactical positioning, i.e., movements of individual or small groups of howitzers in response to battlefield conditions.) An annual period, however, can encompass many different and unique environments, each with a different and unique workload and set of manpower requirements. The mission requirement for ESPAWS is to operate effectively until the N-th day of battle; ARRADCOM's guidance indicated a range of 3 to 10 days. For purposes of

this study, a seven day period was selected. This permitted calculation of a standard work week, consisting of the elements shown in Table 6-1.

This work week and associated values were developed using MACRIT as a guide. The non-productive hours associated with messing and personal needs were factored out of the time available for work. This decision was consistent with MACRIT methodology in that sleep is not considered by MACRIT as time available for work. Unit movement was considered as a percent (from MACRIT) of the 77 hour work week and includes tactical deployment. It is interesting to note that the implied manpower requirements per operating station in MACRIT (double shift -- 24 hours, 12 hours each shift) would exceed a standard work week of 77 hours (11 hours per shift).

6.3.2 Identify Workload Categories

The next step in determining ESPAWS manpower requirements was to identify workload categories. The proper workload categories were those which existed in the projected mission environment and were necessary to fulfill required mission capabilities. Workload categories were identified and defined as follows:

1. Operations

   Operational Manning (OM). Workload required to fulfill the mission capabilities of communication and mobility. Mobility here includes only tactical positioning.

2. Maintenance

   Scheduled Maintenance (SM). Workload, measured in manhours, required for performance of routine maintenance activities that are scheduled on the basis of equipment usage.

   Unscheduled Maintenance (UM). Workload required to restore equipment or materiel to operating condition.

Table 6-1 ESPAWS STANDARD WORK WEEK

1. **Analysis of Available Hours**

Total Hours Available Weekly (24x7)		168
Minus:	Sleep (8x7)	56
	Messing (2x7)	14
	Personal Needs (3x7)	21
Total Available for Work		77

2. **Analysis of Work Week**

Operator:	Operation	56.00
(Crew)	Scheduled Work	1.75
	Unit Movement Allowance	19.25
Total Work Week		77.00
Non-Operator:	Scheduled Work	40.00
(Organizational)	Unscheduled Work	17.75
	Unit Movement Allowance	19.25
Total Work Week		77.00

Preventive Maintenance Checks and Services (PMCS). Same definition as SM, but event rather than usage driven.

Two points about this categorization must be made:

While no category was established for performing primary fire tasks, the capability (manpower) to perform them must always be present. Because the time spent in primary fire tasks is not predictable no clock time is attached to or identified for this function. It is assumed that primary fire tasks when they occur will absorb the available work time of available personnel. Thus the manpower necessary to fire is defined by the lower limit of the manpower requirement.

An allowance for unit movement must be considered. The time associated with unit movement (19.25 hours per week, from MACRIT) is over and above the requirement for the tactical positioning capability contained in operational manning. Hence, unit movement should be treated as workload. However, it is also a component of the standard work week as a fixed allowance, which reduces the time available for other work. Thus, a further modification is necessary. Since the tasks associated with both tactical positioning and unit movement are essentially identical, the capability to perform the lesser requirement is subsumed under the capability to perform the greater requirement. Unit movement is the lesser requirement for mobility and, hence, can be excluded from the standard work week. The variable manpower requirement for operational and maintenance workload can then be considered separately.

The general manpower requirements equation can then be stated as:

$$\frac{\text{WORKLOAD}}{\text{WORK WEEK}} = \frac{\text{OM} + \text{SM} + \text{UM} + \text{PMCS}}{57.75} = \text{MANPOWER}$$

It is not coincidental that this equation resembles the current MACRIT formula. The simplicity of the equation was an asset in the development of manpower requirements. As with the current MACRIT process, it was recognized that any shortcomings in the results would be due to shortcomings in the development of workload and work week estimates. The need to use estimates that are as accurate as possible prompted the analysis of these areas prior to the development of manpower requirements.

6.3.3 Determine Crew Manpower Requirements

The assumption set and the standard work week developed in 6.3.1 allowed computation of a lower limit for crew manpower requirements. If the time available for work is 77 hours per week, and the most stringent workload requirement calls for 24 hours per day or 168 hours per week, then the minimum manpower requirement is 2.18 or a minimum of three personnel. Thus, the separate manpower requirements for each of the general workload categories, operational and maintenance, had to equal or exceed three when aggregated.

The development of OM workload for the reference system commenced with computing the actual clock time per week associated with the mobility capability. A weighted average technique was applied to the movement specifications contained in the MP/OMS. This approach integrated the various times associated with mission profiles of surge, intense, and sustained operations based on relative percent of total time spent in each profile. Set-up and breakdown times were also derived from the MP/OMS. The calculations to determine clock time per week associated with mobility are graphically displayed in Table 6-2. The end result is 40.05 hours clock time per week to fulfull the mobility requirement.

The next step in the development of OM workload was the identification of required operating stations. This step required a thorough analysis of the reference system equipments and associated subsystem functional requirements to develop operator tasks. Finally, these tasks were aggregated into operating station requirements. Care was exercised to ensure that, if the multitude of tasks and/or complexity of tasks associated with any one operating station exceeded the capability of a single operator, additional and identical operator stations would be identified.

TABLE 6-2. MOBILITY COMPUTATIONS

1.	SET UP/BREAK DOWN TIME			
	a. MISSION PROFILE (WEEK):	SUSTAINED (S) = 49 MOVES, INTENSE (I) = 84 MOVES, SURGE (G) = 112 MOVES		
	b. % TIME:	.5S + .4I + .1G = 69 MOVES/WEEK		
	c.	$\frac{\text{26 MIN/MOVE X 69 MOVES/WEEK}}{\text{60 MIN/HOUR}}$	=	29.9 HOURS/WEEK
2.	TRANSIT TIME			
	a. MISSION PROFILE (WEEK):	SUSTAINED (S) = 73.5 MILES, INTENSE (I) = 119 MILES, SURGE (G) = 171.5 MILES		
	b. % TIME:	.5S + .4I + .1G = 101.5 MILES/WEEK		
	c.	$\frac{\text{101.5 MILES/WEEK}}{\text{10 MILES/HOUR*}}$	=	10.15 HOURS/WEEK
3.	TOTAL MOBILITY TIME:	29.9 HOURS/WEEK + 10.15 HOURS/WEEK	=	40.05 HOURS/WEEK

*Average MPH based on lowest expected speed over three types of movement surfaces.

Two operating stations were identified for accomplishing mobility mission requirements -- a Crew Chief/Communicator and a Driver.

The clock time associated with communications capability is 24 hours per day, 168 hours per week, and one operating station was identified; however, this station need not be totally dedicated to communications. For this reason, it was combined with the crew chief station and, therefore, requires dedicated manning of only 127 hours/week.

This OM workload data was then formatted into an OM task/event network. A task/event network is primarily a "bookkeeping" device. It has several distinct advantages, most important of which are (1) the ability to support an audit trail, (2) the ready identification of "high drivers", and (3) the ease with which the data may be reformatted to support different analytical processes. The OM task/event network for the reference system is shown in Figure 6-2.

The development of the reference system's OM workload allowed the first step to be taken toward the development of manpower requirements based on integrated workload (operator/maintainer).

This step, derive OM manpower requirements, is based on the premise that OM workload, at the crew level, will be the high driver of manpower. Identification of these manpower requirements began the process, which continued by the addition of other categories of workload to those OM driven manpower requirements until the "work week" of each was filled. Additional manpower was driven to fulfill any remaining workload requirements. Finally, the manpower requirement to perform primary fire tasks was analyzed to ensure that it was resident at all times within the previously developed manpower set.

The developed OM manpower requirements and associated "Remaining Hours Available" are shown in Table 6-3.

The skill and skill level requirements were developed from criteria as outlined in the Enlisted Career Management Fields and Military Occupational Specialties (AR 611-201) and the Soldier and Commander's manuals for MOS 13B. Further, analyses of current skill levels in the predecessor system crew and skill level requirements in existing systems with independent operation capabilities were conducted to ensure an accurate estimate of skill level requirements. It should be noted that while these manpower requirements were derived for the reference system, they will remain true for

Figure 6-2 REFERENCE SYSTEM OPERATIONAL MANNING (OM) TASK/EVENT NETWORK

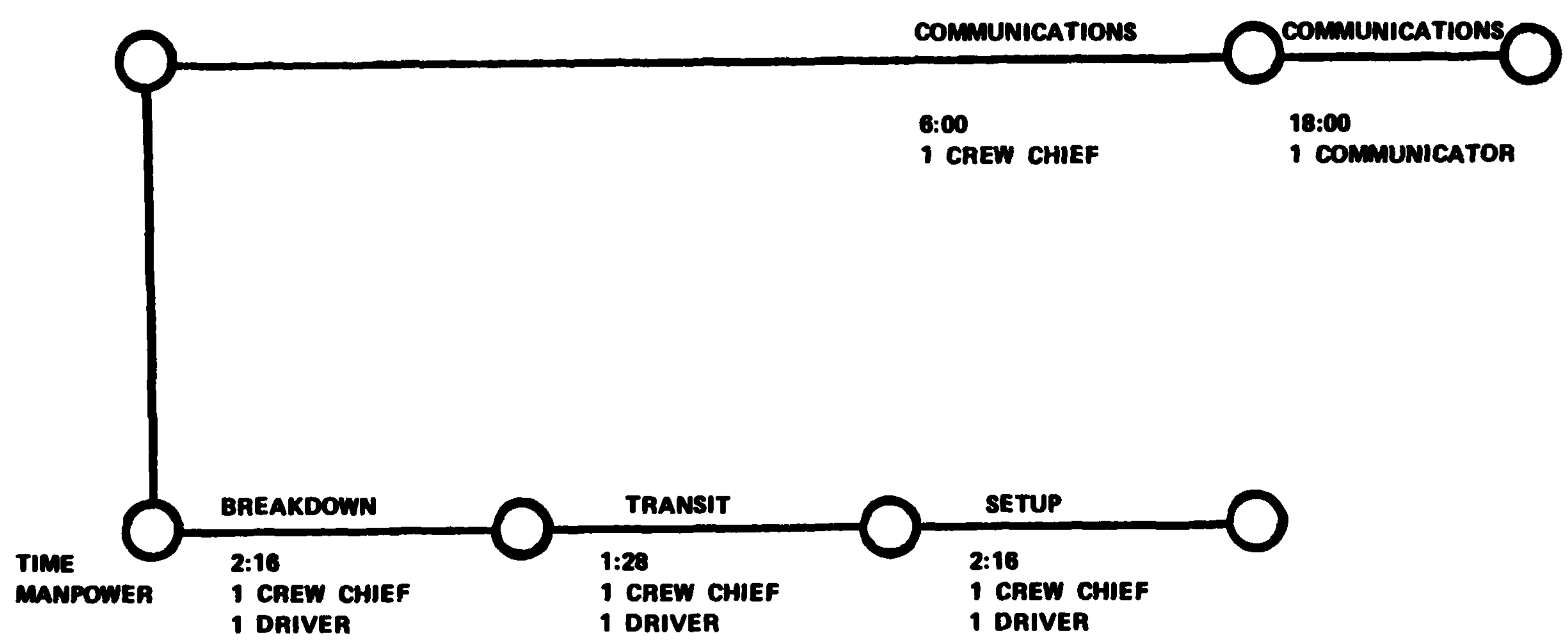


Table 6-3. Operational Manning (OM) Manpower Requirements.

Title	Skill	Level	OM	Remaining Workload
Crew Chief/ Communicator	13B30	E6	52.5*	5.25
Driver	13B10	E4	40.05	17.7
Communicator	13B10	E3	57.75	0
Communicator	13B10	E3	57.75	0

*includes 12.45 hours as sole communicator

the conceptual system as (1) the projected mission environment is identical, and (2) no design difference was found to impact on this workload category.

The development of reference system maintenance workload data provide a unique opportunity to test the flexibility of the HARDMAN manpower requirements analysis. Historical R&M data in raw form was collected from a variety of sources, normalized to meet the projected mission environment, and then structured into the reference system task/event networks. The normalization was a quantitative and qualitative process in that in many cases, such as the automatic ammunition loader, the data was non-Army, and in this case, Navy. This required the normalization or translation of quantitative and qualitative Navy maintenance manhours into quantitative and qualitative Army maintenance manhours. The approach used to determine the differences in number of maintenance manhours was to utilize an Army scenario and, through a rigorous engineering analysis, determine required maintenance changes resulting from changes in scenario (Navy to Army). Qualitative changes were accomplished through what was essentially compatibility analyses between Navy occupational standards as stated in NAVPERS 18068D and Army occupational standards as stated in AR 611-201.

The data obtained from the Army SDC required some normalization in that it reflected the actual work being performed and who was doing it, rather than what was required to be done and who was required to do it. A representative maintenance task/event network is shown in Figure 6-3.

The maintenance manhours were then aggregated by the required skill and skill level. The results are shown in Table 6-4 as the reference system maintenance manhours. A productivity allowance of 40 percent was added to obtain the final number. This allowance is consistent with the maximum allowed by MACRIT and is considered to be a valid estimate given the projected mission environment. Maintenance manpower was then determined by using the general manpower equation, and integrating the results into existing OM manpower; the result of this integration is shown in Table 6-5.

The next step was to transform the historically-derived reference system maintenance workload data into similar data for the conceptual system. This was accomplished through an engineering determination of design differences between the reference and conceptual system equipments.

Figure 6-3 GENERALIZED MAINTENANCE TASK/EVENT NETWORK

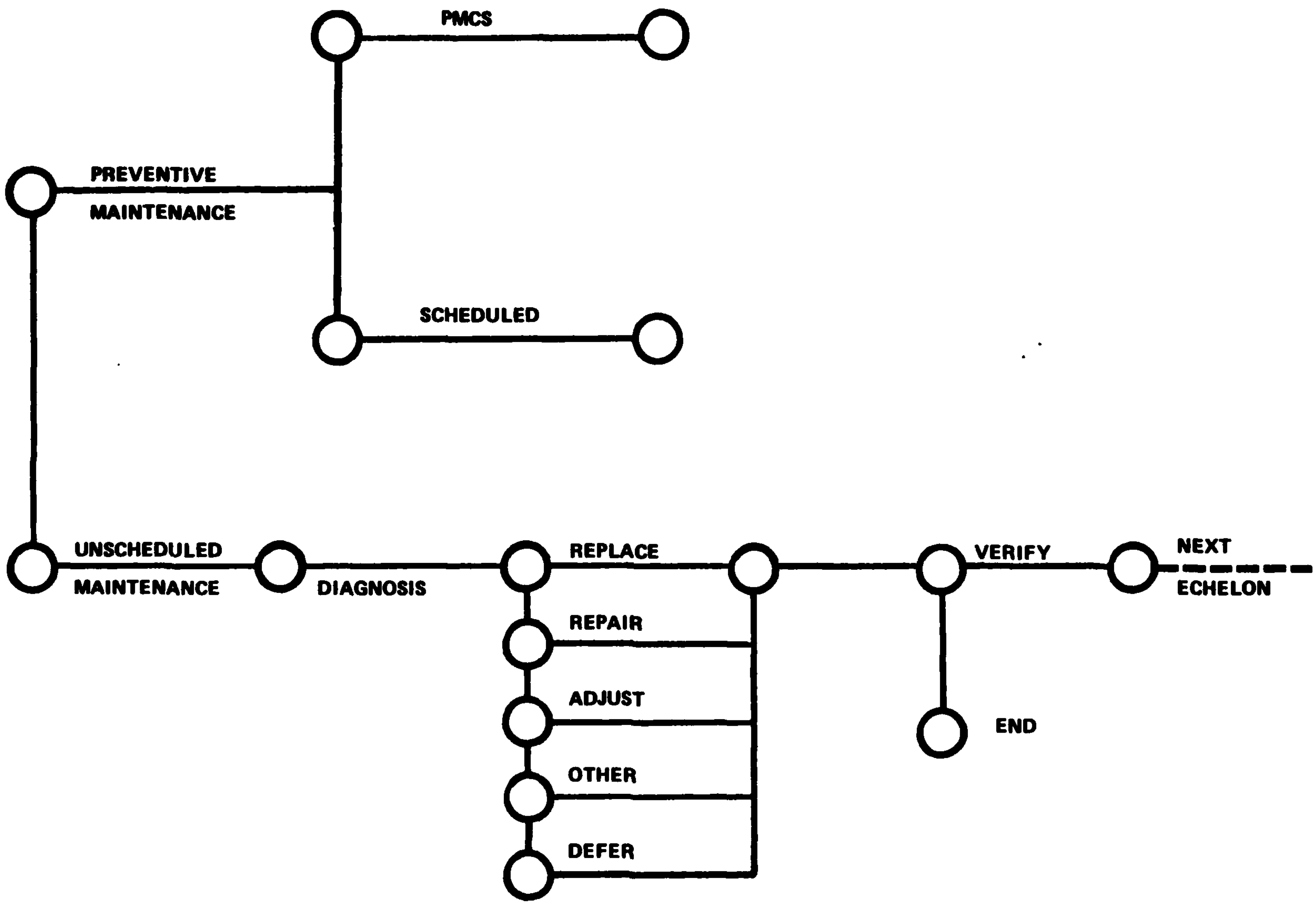


Table 6-4 REFERENCE SYSTEM

AGGREGATE WEEKLY MAINTENANCE MANHOURS

MOS/ Skill Level	Grade	MMH	PA*	Total
13B30	E6	1.218	.487	1.71
13B20	E5	11.921	4.768	16.689
13B10	E4	33.775	13.51	47.285
13B10	E3	6.664	2.666	9.33

*Productivity Allowance (PA) = .4 x MMH; (from MACRIT)

Table 6-5 REFERENCE SYSTEM

CREW MANPOWER REQUIREMENTS

	MOS/ Skill Level	Grade	OM	MMH	Total
Crew Chief/ Communicator	13B30	E6	52.5	5.25	57.75
Maintenance Tech.	13B20	E5	–	57.75	57.75
Driver	13B10	E4	40.05	12.01	52.06
Communicator	13B10	E3	57.75	–	57.75
Communicator	13B10	E3	57.75	–	57.75

Section 5.3 discussed the determination of the design differences between the reference and conceptual ESPAWS designs. Those parameters of interest considered design-influential were further assessed for their scope of impact. Analysis was devoted to the development of perturbation factors involved in deriving the anticipated changes in workload for the conceptual design. As also discussed in Section 5.3, in some cases (Fire Control Computer, AHRS) the perturbation values were explicit, namely the change in the RAM parameters of interest provided by replacement of reference equipments with technologically-advanced conceptual equipments. In other cases, (autoloader and improved automotives) perturbation values were derived from contractor estimates, and normalized to include the actual experience represented by the historical reference system data. However derived, perturbation values were then applied to the reference system task/event networks of interest to derive similar networks for the conceptual system.

The resulting conceptual system maintenance task/event network workload data was then aggregated in a manner similar to reference system data aggregation to derive qualitative and quantitative manhour requirements. These maintenance requirements are shown in Table 6-6. It was then necessary to integrate this workload into the existing OM manpower requirements. Table 6-7 shows the results of this integration.

Development of the crew level ESPAWS manpower requirements was then complete with two exceptions, the addition of KP and security workload, and the analysis of the resulting manpower requirements set to ensure that the capability, to perform primary fire tasks, was resident in that set.

KP and security workload are indirect as they do not directly contribute to ESPAWS primary mission. In fact, the KP manpower requirement more appropriately belongs in the messing facility supporting the ESPAWS unit. Personnel to fill this requirement could be allocated to various units as appropriate by the commander and then drawn upon in proportion to the allocation to fulfill this requirement. This type of workload and manpower is not within the scope of this study; however, because it is a part of MACRIT allowances, it was calculated and separated to show its impact on ESPAWS manpower. The workload was developed from the MACRIT allowance and is 1.69 hours per week KP and 4.49 hours per week security for a total of 6.18 hours per week.

Table 6-6 CONCEPTUAL SYSTEM

MOS/ Skill Level	Aggregate Weekly Maintenance Manhours Grade	MMH	PA*	Total
13B30	E6	1.19	.476	1.666
13B20	E5	11.704	4.682	16.386
13B10	E4	28.896	11.558	40.454
13B10	E3	8.645	3.458	4.693

*Productivity Allowance (PA) = .4 x MMH; (from MACRIT)

Table 6-7 CONCEPTUAL SYSTEM CREW MANPOWER REQUIREMENTS

Title	MOS/ Skill Level	Grade	OM	MMH	Total
Crew Chief/ Communicator	13B30	E6	52.5	5.25	57.75
Maintenance Tech	13B20	E5	–	57.75	57.75
Driver	13B10	E4	40.05	.199	40.398
Communicator	13B10	E3	57.75	–	57.75
Communicator	13B10	E3	57.75	–	57.75

The required skill and level is E-2. The addition of this workload to the existing reference system manpower drives another requirement as only 5.69 hours per week were available. The addition of another manpower requirement to accomplish .5 manhours work per week was considered excessive, especially in view of the other indirect workload which is not considered by MACRIT and also not within the scope of this study. This area of indirect or support functions requires further detailed analysis, as a significant amount of unidentified workload could and probably does exist. For the purpose of this study, both reference and conceptual system manpower requirements will not cover KP and security.

The final step, to ascertain if the capability to perform primary fire task is resident in the crew manpower requirement set that has been developed, was accomplished using the Howitzer Crew Size Model, developed by ARI, to analyze firing station requirements given conceptual and reference system equipments.

The equipment capabilities of the ESPAWS design were analyzed, and it was determined that if all equipments were functioning properly, it would require two operators to accomplish a primary fire task. These positions were identified as Chief of Section and Gunner in accordance with standard terminology. These requirements are well within the manpower requirements set developed.

The availability of three additional positions in the developed set led to further analysis of what equipment failures could be sustained and still allow accomplishment of the primary fire task. A computer and/or data link failure would require three positions manned, the two previously mentioned and one of assistant gunner. In this configuration, the gunner and assistant gunner would disable the computer inputs and manually insert elevation, train, and fuze set orders as relayed by the Chief of Section into the electrohydraulic cannon drives. Some degradation of response time would occur; however, it would still be within specified requirements. The other single failure analyzed was the loss of the autoload capability. This would require three loaders or cannoneers in addition to the Chief of Section and Gunner. Again, some response time degradation would occur; however, it would still be within specifications. A multiple failure consisting of the two previous failures was analyzed and, by utilizing all five positions available, it was found that while the system would perform a primary fire task, it would not be able to obtain the minimum acceptable response time.

The crew manpower requirements for both reference and new systems are shown in Table 6-8. The position names have been normalized to be consistent with current terminology.

6.3.4 Determine Organizational Level Manpower Requirements

The development of organizational level manpower requirements was simplified in that only maintenance workload was considered. Workload categories of scheduled, unscheduled, and preventive maintenance checks and services were again utilized. The standard work week as developed in Section 6.3.1 was also used to ensure consistency in manpower requirements development. It is important to note, however, that while only maintenance manpower requirements were considered, this workload did not represent total organizational level workload. Again, those areas of workload which are "indirect" such as meetings, training supervision, administration, etc., were not included as they are not within the scope of this study. This type of workload can be significant, especially at a maintenance-type activity and should be defined and taken into consideration in the development of total activity manpower requirements.

Workload data from two sources, Army SDC and Navy Maintenance Data Collection System (MDCS), were used to develop reference system maintenance workload data. As in the case of crew level data, it was necessary to normalize both Army and Navy raw data. Navy data was translated into Army workload data through changes in scenario and skill, and skill level transformations. The Army SDC data reflects tasks which are being done today and who, in reality, is doing them. For this reason, workload quantity and required quality were suspect in that "who is doing it" might or might not be "who is required", and any improper quality could affect MMH to accomplish a reported task. The raw SDC data was normalized to minimize these errors. (e.g., a task normally performed by one MOS, but appearing in an SDC record against an MOS not usually associated with the maintenance echelon or the type of unit, was included in the workload for the normal MOS.) However, the level of the available data dictated a general approach. A precise approach would require an analysis of more detailed and more specific task data. While the general approach provided valid estimations at this point in the WSAP, analysis of better, more detailed task data would be required in latter stages of the WSAP.

Table 6-8. Crew Manpower Requirements

Title	MOS	Paygrade
Chief of Section (crew chief/communicator)	13B30	E6
Gunner (maintenance technician)	13B20	E5
Assistant Gunner (communicator)	13B10	E3
Cannoneer No. 1 (communicator)	13B10	E3
Cannoneer No. 2 (driver)	13B10	E4

Following data normalization, the reference system workload was formatted into task/event networks for the application of perturbation values. The next step consisted of aggregating the workload data by MOS and grade level, and adding a productivity allowance of 40 percent. The results of this aggregation are shown in Table 6-9. Finally, the development of an individual unit's maintenance manpower requirement was accomplished by multiplying the MMH per weapon by weapon density, in this case 24.

The resulting workload was then distributed to different positions utilizing the following guidelines (1) workload quality requirements could be filled by a higher but never lower skill level, and (2) each position identified was assigned the maximum number of manhours without exceeding the standard work week limit. The results of this step are shown in Table 6-10.

After applying perturbation values to the reference system workload data, the resulting conceptual system workload data was aggregated and distributed to positions in the same manner as was the reference system workload data. The results of the aggregation are shown in Table 6-11, and the manpower requirements for a conceptual system unit in Table 6-12.

In summary, then, after minor modification, the HARDMAN manpower requirements analysis was capable of developing accurate estimates of manpower requirements in an emerging system. Equally important, the analysis was conducted from a foundation based on current and approved Army methodology for determining manpower requirements.

Table 6-9 REFERENCE SYSTEM MAINTENANCE MANHOURS PER WEEK

MOS	Grade	MMH	Productivity Allowance	Total
13B	E2	.028	.011	.039
13B	E3	.245	.098	.343
13B	E4	5.957	2.383	8.340
13B	E5	1.771	.708	2.479
13B	E6	.056	.022	.078
13B	E7	.014	.006	.020
31V	E3	2.968	1.187	4.155
31V	E4	24.059	9.624	33.683
31V	E5	22.708	9.083	31.791
41C	E4	.182	.073	.255
45K	E3	2.107	.843	2.950
45K	E4	10.08	4.032	14.112
45K	E5	5.789	2.316	8.105
44B	E3	.014	.006	.020
44B	E4	.072	.029	.101
45L	E3	.707	.283	.990
45L	E4	6.951	2.78	9.731
45L	E5	.763	.305	1.068
63B	E4	.028	.011	.039
63B	E5	.014	.006	.020
63B	E6	.042	.017	.059
63C	E4	2.541	1.016	3.556
63C	E5	3.0	1.2	4.2
63C	E6	.707	.283	.990

Productivity Allowance = .4 x MMH; (from MACRIT)

Table 6-10 REFERENCE SYSTEM UNIT MANPOWER REQUIREMENTS

Number	MOS	Grade	Remarks
1	13B	E7	
1	63B	E6	*54.918 hours remain
1	63C	E6	
1	13B	E5	
14	31V	E5	
4	45K	E5	
1	45K	E5	
2	63C	E5	
4	13B	E4	*25.77 hours remain
14	31V	E4	
1	41C	E4	*51.63 hours remain
6	45K	E4	
1	44B	E4	*54.846 hours remain
1	45L	E4	*5.814 hours remain
1	63C	E4	*21.096 hours remain
1	31V	E3	*3.654 hours remain
1	45K	E3	*31.61 hours remain

Total: 58

*hours still available for work

By Paygrade

E7	E6	E5	E4	E3	Total
1	2	22	31	2	58

By MOS

	13B	31V	41C	44B	45K	45L	63B	63C
E7	1	00	0	0	0	0	0	0
E6	0	0	0	0	0	0	1	1
E5	1	14	0	0	4	1	0	2
E4	4	14	1	1	6	4	0	1
E3	0	1	0	0	1	0	0	0
Total	6	29	1	1	11	5	1	4

Table 6-11 CONCEPTUAL SYSTEM MAINTENANCE MANHOURS PER WEEK

MOS	Grade	MMH	Productivity* Allowance	Total
13B	E2	.028	.011	.039
13B	E3	.245	.098	.343
13B	E4	2.877	1.151	4.028
13B	E5	1.771	.708	2.479
13B	E6	.056	.022	.078
13B	E7	.014	.006	.020
31V	E3	2.968	1.187	4.155
31V	E4	.056	.022	.078
41C	E4	.182	.073	.255
45K	E3	2.107	.843	2.950
45K	E4	10.08	4.032	14.112
45K	E5	5.789	2.316	8.105
44B	E3	.014	.006	.020
44B	E4	.072	.029	.101
45L	E3	.707	.283	.990
45L	E4	5.656	2.262	7.918
45L	E5	.763	.305	1.068
63B	E4	.007	.003	.101
63B	E5	.014	.006	.020
63B	E6	.021	.009	.030
63C	E4	2.17	.868	3.038
63C	E5	2.786	1.114	3.900
63C	E6	.665	.266	.931

*Productivity Allowance = .4 x MMH; (from MACRIT)

Table 6-12. CONCEPTUAL SYSTEM MANPOWER REQUIREMENTS.

Number	MOS	Grade	Remarks
1	13B	E7	
1	63B	E6	*56.31 hours remain
1	63C	E6	
1	13B	E5	
4	45K	E5	
1	45L	E5	
2	63C	E5	
1	13B	E4	
1	31V	E4	
1	41C	E4	*51.63 hours remain
6	45K	E4	*54.846 hours remain
1	44B	E4	
3	45L	E4	
1	63C	E4	*42.144 hours remain
1	13B	E3	*52.68 hours remain
1	45K	E3	*31.61 hours remain
1	45L	E3	*18.654 hours remain
1	31V	E2	*13.908 hours remain

Total: 29

*hours still available for work

By Paygrade

E7	E6	E5	E4	E3	E2	Total
1	2	8	14	3	1	29

By MOS

	13B	31V	41C	44B	45K	45L	63B	63C
E7	1	0	0	0	0	0	0	
E6	0	0	0	0	0	0	1	1
E5	1	0	0	0	4	1	0	2
E4	1	1	1	1	6	3	0	1
E3	1	1	0	0	1	1	0	0
E2	0	0	0	0	0	0	0	0
Total	4	2	1	1	11	5	1	4

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SECTION 7
DETERMINE PERSONNEL REQUIREMENTS

7.1 OVERVIEW

This section describes the Personnel Requirements Analysis of the HARDMAN methodology, and its application to ESPAWS. In adapting HARDMAN to meet Army needs, parts of the analysis were modified because of: (1) obvious differences between Navy and Army structure and policy, and (2) insufficient school history data. However, the basic framework of the Personnel Requirements Analysis was deemed appropriate and remained essentially unchanged for this application.

The objective of personnel requirements determination is to derive the size and structure of the personnel pipelines which will support specified predecessor, reference, and conceptual system manpower requirements, given the effects of advancement, attrition, and average time spend in each paygrade. This allows comparisons to be made among the systems in terms of those elements of design which are high drivers of personnel resources, as reflected in requirements for certain Military Occupational Specialties (MOS).

In this context, personnel requirements are defined to differ from manpower requirements in the following way. Personnel must be in supply to meet a twofold requirement: (1) they must meet current system-specific manpower requirements by MOS/ paygrade; and (2) they must be present in sufficient numbers to meet future downstream requirements. The latter requirement is, obviously, due to the procurement policy for personnel; they are always promoted from within as opposed to being "hired" at a particular level. Therefore, there must be a pipeline supply of personnel who are in training or filling another requirement, in order for higher grade level requirements to be filled. The important concept here can be demonstrated as follows. If there is a requirement for one E-9 in a particular MOS, it may be necessary to introduce ten E-1s into the pipeline, due to the relatively low probability of a given individual reaching the E-9 level.

In response to the problem of calculating fill and sustaining levels of personnel supply, the Minimum Flow Solution (MFS) model was developed. It should be stressed

here that this model was created for Navy use and that one of the goals of this study was to assess the feasibility of applying this and other Navy HARDMAN tools and procedures to an Army project. The MFS model determines (1) the number of personnel required by MOS/paygrade to initially fill and sustain specified manpower requirements, and (2) recruit rates, by MOS, which will sustain those levels of personnel. The purpose of calculating these values is primarily for making comparisons of relative MOS demand between particular systems. In the model's present configuration, it should not be construed to produce actual values for personnel management planners to use. There are two reasons for this: (1) the model assumes that there are no personnel existing to meet the requirements, thus calculating an initial fill rate required to start the system up; and (2) since the HARDMAN methodology addresses system-specific requirements, no consideration is given to the assignment of pipeline overhead personnel to other systems. (In order to develop relevant values for personnel planners, the pipelines would have to be considered from a total force perspective.) Therefore, it must be understood that the purpose of this model is solely to make comparisons between system alternatives. These comparisons can be made because the two factors described above will not vary across systems.

7.2 PERSONNEL REQUIREMENTS ANALYSIS IN THE HARDMAN METHODOLOGY

Figure 7-1 provides an overview of the steps in the Personnel Requirements Analysis. Data are collected from outside sources, such as the Enlisted Master File (EMF), and provided by other steps in the methodology. The manpower and training analyses provide the numbers of personnel by MOS and paygrade required for effective operation, maintenance, and support of the emerging weapon system. Together with course information and data extracted from the Enlisted Master File, personnel pipeline flow characteristics can be established. These flow characteristics are established by tracking personnel data through an automated tracking program. The flow characteristics which result -- career paths, advancement and attrition probabilities, average times in paygrade, and sea/shore rotation in Navy applications -- represent average flow of personnel through each MOS.

Flow characteristics are then formatted into pipelines. Each MOS has its own pipeline which represents its unique

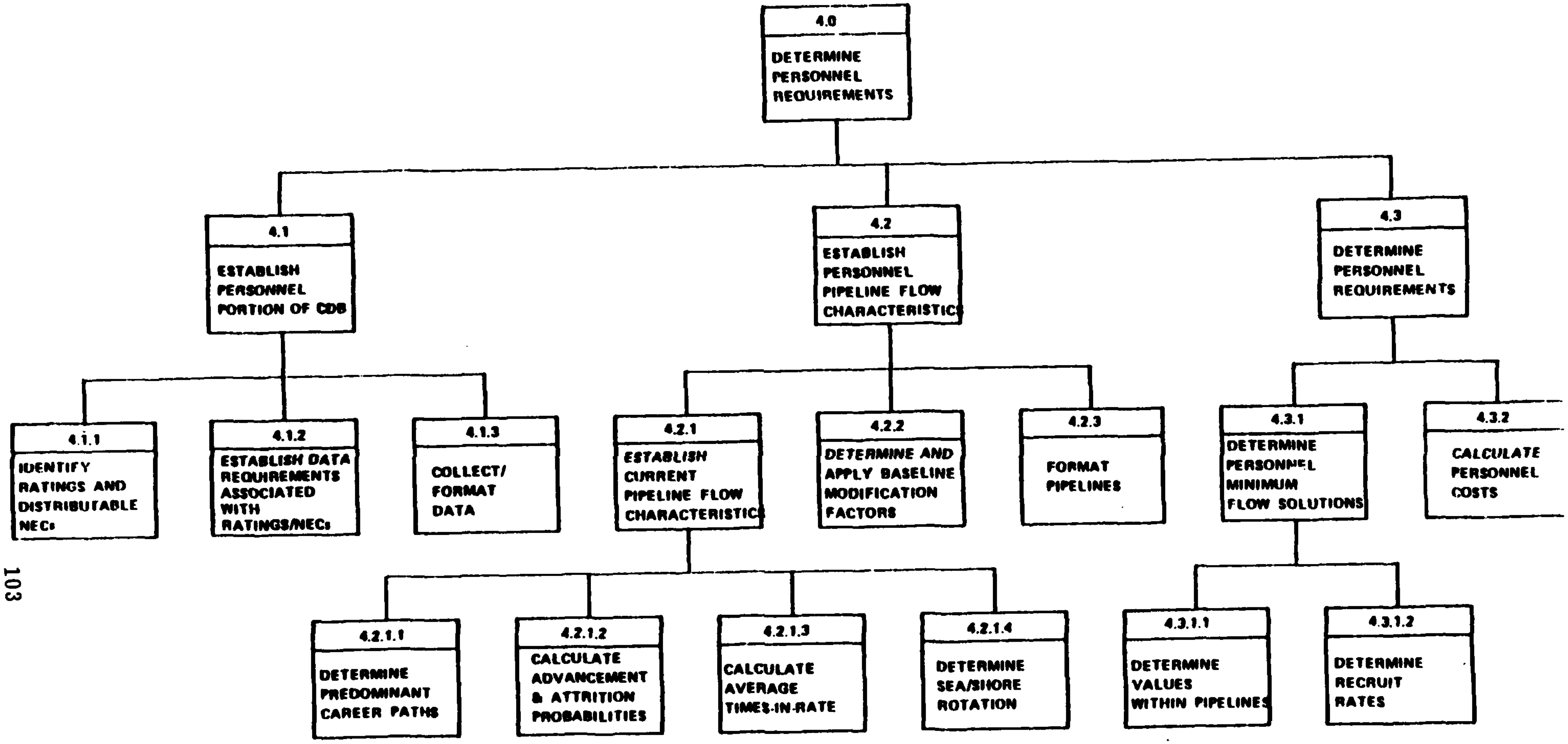


Figure 7-1 STEP 4 (DETERMINE PERSONNEL REQUIREMENTS) HIERARCHY DIAGRAM

flow of personnel through paygrades within that MOS. In addition, each MOS must have a predecessor, reference, and a conceptual pipeline. The statistics gathered on specific paygrades must be formatted into groups by MOS (i.e., the flow characteristics of all of an MOS's paygrades, when combined, represent the flow through that MOS).

Personnel requirements are those which fill manpower requirements while offsetting the effects of advancement/ attrition and rotation requirements. These "extra" pipeline personnel provide the overhead required to fully satisfy current and future manpower needs at all paygrades. The Personnel Requirements Analysis uses the Minimum Flow Solution (MFS) model to determine these pipeline numbers, and also the number of recruits needed to maintain this pipeline. Personnel costs for each paygrade can then be calculated using personnel cost information collected in the beginning of this step.

7.3 APPLICATION TO ESPAWS

This section describes the application of the Personnel Requirements Analysis step of the HARDMAN methodology to the ESPAWS study. Since one of the objectives of this study was to assess the feasibility of applying the methodology, the changes which were made to adapt the models/procedures will be briefly summarized first and will be discussed in greater detail in the rest of this section.

While some of substeps of Personnel Requirements Analysis shown in Table 7-1 were altered in some way, the basic framework of the Personnel Requirements Analysis remained the same and the modifications did not involve substantial reprogramming. A discussion of how the methodology was applied to ESPAWS follows.

7.3.1 Establish Personnel Portion of CDB (Step 4.1)

The procedure of Personnel Requirements Analysis began with the identification, collection, and formatting of data to be included in the Consolidated Data Base. The data collected for this study were principally Enlisted Master File (EMF) extracts. This file, which contains current status of all active Army enlisted personnel, was obtained in quarterly snapshots of the following dates: September 1979; December 1979; March 1980; June 1980; and October 1980.

Table 7-1. Summary of Modifications to the Personnel Requirements Step of the HARDMAN Methodology.

Substep	Reason
Determine Predominant Career Paths	Since career paths were not definable, due to a lack of data on the Enlisted Master File (EMF), AFQT categories were substituted in order to provide a meaningful and useful analysis.
Determine Sea/Shore Rotation	Sea/shore rotation was not addressed in this application, since it is not a basis for the types of requirements individuals fill, as it is in the Navy.
Format Pipelines	*Since the Army does not have* unspecialized pools of E-1 to E-3 personnel (as does the Navy), each MOS was considered to have its own progression from E-1 on.
Determine Minimum Flow Solution (MFS)	The MFS model was modified to encompass the following changes: • No sea/shore rotation • Uses AFQT category, rather than career paths • Includes additional sensitivity analysis capabilities

Since the January 1981 extract was not received in time for the analysis, only those tapes prior to October 1980 were analyzed. CMF 63 underwent a change at that time, and since there was only one data point with new information, no statistics could be formulated. Therefore, the four tapes covering the period of September 1979 to June 1980 were used for the analysis. (See Appendix A4 for a description of the data contained in the tapes.)

7.3.2 Establish Personnel Pipeline Flow Characteristics (Step 4.2)

Personnel data were formulated into descriptive personnel flow characteristics, unique for each MOS. This was performed through a tracking procedure which detects and records changes in individual personnel status. The following parameters were used to define personnel flow:

- AFQT category percentages
- Advancement rates
- Attrition rates
- Average time-in-paygrade (advancers)
- Average time-in-paygrade (attriters)

These statistics are the basis for inputs which go into the Minimum Flow Solution model. The other input to the model is manpower requirements.

Figure 7-2 shows the MOSs which are involved with the ESPAWS study and the paygrades within them to be analyzed. The figure shows the career progressions of these MOSs; the blocks which are outlined represent the paygrades under study. The unit which was analyzed was paygrade rather than skill level, because paygrades are convertible to skill levels; the reverse is not true.

The analysis continued with the formulation of personnel pipeline flow characteristics. These statistics, as derived from the quarterly EMF tracking procedure, represent the flow of each MOS as determined from historical trends.

The first step in the tracking procedure was to assess the feasibility of constructing career paths for each MOS. This process became impossible due to the lack of data in two

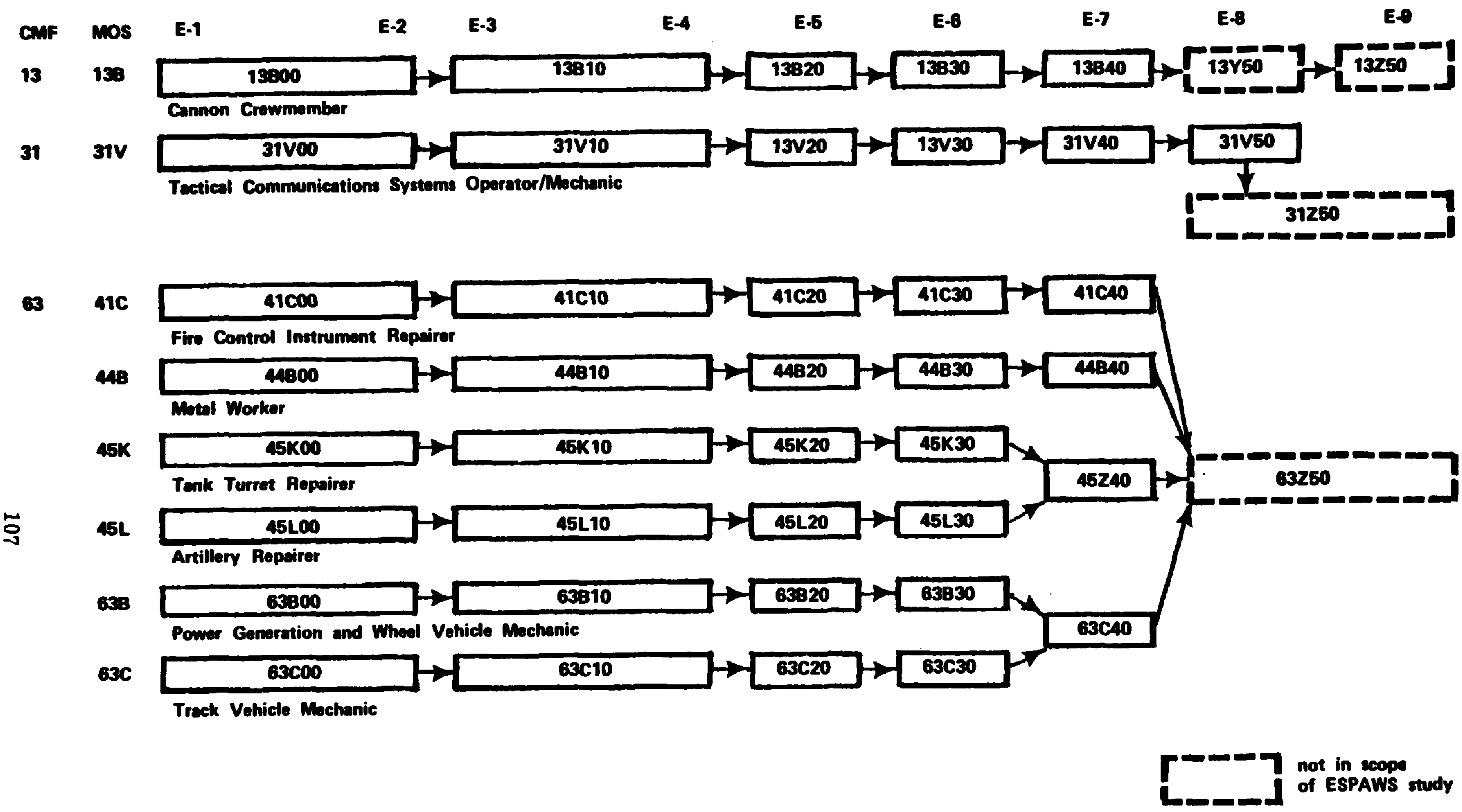


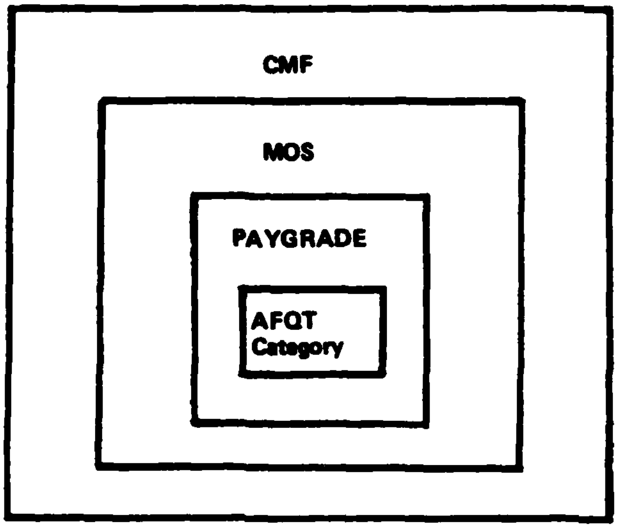
Figure 7-2. ESPAWS-related MOS career progressions.

specific fields on the Enlisted Master File: Non-Commissioned Officer (NCO) Education System field and Advanced Individual Training (AIT) graduation date. If they had been complete, it would have been possible to determine the path an individual was on (basically, formal school vs. on-the-job experience). However, in the NCO education system field, approximately 94 percent of all individuals had a blank in this field, and in the AIT graduation date fields, 54 percent were blank. Because of the problems associated with obtaining career path data for specific individuals, it was decided not to break MOSs into separate career paths. The MOSs pertaining to the ESPAWS study are shown in Figure 7-3.

As an alternative, although it is not meant to be a substitute, MOSs were grouped by Armed Forces Qualification Test (AFQT) category (as it appears in the AFQT score group field of the EMF), and statistics were calculated separately for each group. This was done for several reasons: (1) to test the hypothesis that these groups have very different statistics, such as attrition rates and average times-in-paygrade; (2) to analyze the differences, if any, and correlate them to appropriate distributions of personnel within each MOS; and (3) to focus the analysis on another factor, given that career paths were not definable. The distribution of individuals in each score group in each MOS were determined, and percentages were calculated. See Table 7-2 for an example of this calculation. In this example, 1.4 percent of the 13B population in AFQT category 1; 10.1 percent in category 2; 73.6 percent in category 3; 14.7 percent in category 4; and 0.2 percent in category 5.

Next, attrition and advancement probabilities were calculated for each MOS/paygrade/AFQT category. This was done by following individuals across successive quarters of data and noting those individuals who have had a change in the status of their MOS/paygrade. If an individual increased in paygrade, an upgrade was tabulated. If an individual left the MOS or the Army, this was noted as an attrition. This is due to the fact that an individual who leaves is a loss to that MOS, no matter how it occurs. Demotions were not considered, due to their relative infrequency. Notice then that the probability of ultimately advancing or attriting from a paygrade must equal one. (See Table 7-3, which shows attrition and advancement probabilities.) In this case, for example, 13B E-3's in AFQT category 3 attrite 21.2 percent of the time and advance 78.8 percent of the time.

a. Advancement/Attrition Probability Subgroups



b. Average Time-in-Paygrade Subgroups

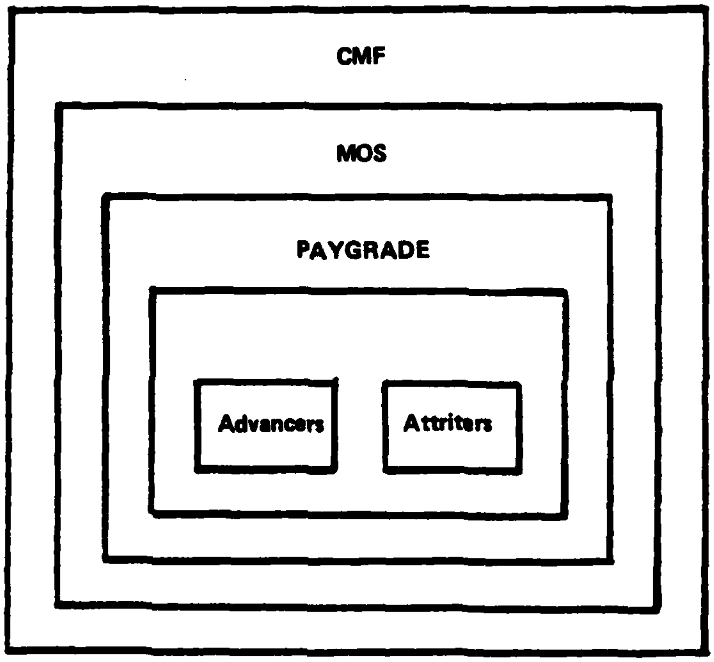


Figure 7-3. Subgroups for personnel analysis.

Table 7-2. AFQT Category Distribution.

MOS	AFQT CATEGORY 1	2	3	4	5
13B	0.0138	0.1008	0.7366	0.1473	0.0016
31V	0.0444	0.2331	0.6290	0.0887	0.0048
41C	0.0206	0.1416	0.6755	0.1622	0.
44B	0.0285	0.1604	0.6929	0.1161	0.0020
45K	0.0213	0.2047	0.7231	0.0509	0.
45L	0.0290	0.1884	0.7319	0.0507	0.
63B	0.0157	0.1403	0.6909	0.1526	0.0005
63C	0.0208	0.1761	0.7068	0.0953	0.0010

Table 7-3. Attrition/Advancement Percentages — Sample

		PROBABIBILITY ATTRITION AFQT CATEGORIES					PROBABILITY ADVANCEMENT AFQT CATEGORIES				
MOS		1	2	3	4	5	1	2	3	4	5
13B	1	0.2571	0.2369	0.2265	0.1507	0.	0.7429	0.7631	0.7735	0.8493	1.0000
	2	0.2115	0.1834	0.1550	0.1200	0.	0.7885	0.8166	0.8450	0.8800	1.0000
	3	0.1233	0.2099	0.2115	0.1814	0.3333	0.8767	0.7901	0.7885	0.8186	0.6667
	4	0.5584	0.6455	0.7360	0.7553	0.5000	0.4416	0.3545	0.2640	0.2447	0.5000
	5	0.7941	0.6792	0.6741	0.5878	0.7500	0.2059	0.3208	0.3259	0.4122	0.2500
	6	0.9167	0.6822	0.7473	0.5758	0.5882	0.0833	0.3178	0.2527	0.4242	0.4118
	7	0.	1.0000	0.9467	1.0000	0.	0.	0.	0.0533	0.	0.
31V	1	0.1053	0.2056	0.3492	0.3600	0.	0.8947	0.7944	0.6508	0.6400	0.
	2	0.0833	0.1596	0.2037	0.0435	0.	0.9167	0.8404	0.7963	0.9565	0.
	3	0.1538	0.1981	0.1350	0.1739	0.	0.8462	0.8019	0.8650	0.8261	0.
	4	0.6667	0.6447	0.7064	0.6250	0.	0.3333	0.3553	0.2936	0.3750	0.
	5	0.7000	0.6875	0.4699	0.3529	1.0000	0.3000	0.3125	0.5301	0.6471	0.
	6	0.5000	0.4016	0.5401	0.5570	0.5455	0.5000	0.5984	0.4599	0.4430	0.4545
	7	0.6667	0.9429	0.8286	0.7727	0.	0.3333	0.0571	0.1714	0.2273	0.
	8	1.0000	1.0000	1.0000	1.0000	1.0000	0.	0.	0.	0.	0.
41C	1	1.0000	0.4286	0.3600	0.3600	0.	0.	0.5714	0.6400	0.6400	0.
	2	0.	0.	0.26[illegible]							
	3	0.	0.								
	4	0.33[illegible]									

Average lengths of time-in-paygrade were calculated for advancer/attriter groups within MOS/paygrade. These average times allow for the construction of an average "profile" of an individual in a particular MOS/paygrade. For example, in Table 7-4, it can be seen that 13B E-4s in AFQT category 3 spend an average of 19.7 months in that paygrade before attriting and 24.6 months before advancing.

Finally, a count of the inventory of MOSs was made. Table 7-5 shows a sample from the output. For 13B, there are 4633 E-1s, 2527 E-2s, 4706 E-3s, etc.

7.3.3 Determine Personnel Requirements (Step 4.3)

All of the above parameters are inputs to the Minimum Flow Solution (MFS) model, which determines personnel requirements. See Figure 7-4 for an overview of the MFS model. This model computes the numbers of personnel needed to initially fill and subsequently sustain all specified manpower requirements. These values thus include both: (1) personnel requirements needed to fill manpower requirements; and (2) the personnel needed to maintain the "pipelines". All of these requirements are system-specific; therefore, many of the pipeline personnel, while they are not necessarily in direct support of the system, are filling requirements for other systems.

The MFS model is an interactive model, which requires the user to input manpower requirements. It then accesses the data derived from the EMF tapes during personnel flow characteristics determination. It also allows the user to specify a percentage change to advancement and attrition rates, or average time-in-paygrade, to see its effects on the results. Some of the assumptions that the MFS model makes follow:

- All system-specific manpower requirements will be met;
- A person must eventually either advance or attrite from a paygrade; and,
- Assignment policy is a variable (individuals can sometimes be assigned to a requirement with a different paygrade).

Table 7-4. Average Lengths of Time-in-Paygrade — Sample.

MOS	ATTRITE 1		2		3		4		5		ADVANCE 1		2		3		4		5	
13B	9	12.9	66	6.4	1155	6.2	134	7.3	0	0.	26	7.7	277	6.3	5937	6.3	755	6.3	1	6.0
	11	6.7	53	6.5	499	6.3	78	6.8	0	0.	41	6.3	236	5.3	2721	5.5	572	5.7	2	5.5
	9	8.8	68	11.2	611	11.1	115	10.5	2	14.5	64	9.7	256	9.8	2278	9.7	519	10.3	4	9.8
	43	20.4	417	21.6	2133	19.7	426	17.2	1	15.0	34	17.6	229	22.4	765	24.6	136	25.8	1	24.0
	27	11.4	216	16.1	513	16.1	87	20.0	3	28.0	7	25.1	102	30.8	248	29.4	61	31.5	1	44.0
	11	29.9	73	27.2	139	28.6	57	37.1	10	38.6	1	39.0	34	41.2	47	42.3	42	60.8	7	44.9
	0	0.	22	32.3	71	34.8	34	33.2	0	0.	0	0.	0	0.	4	39.6	0	0.	0	0.
	0	0.	0	0.	6	6.3	6	8.0	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.
	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.
31E	0	0.	6	7.3	76	5.9	12	5.8	0	0.	1	16.0	13	5.4	111	5.8	23	6.1	0	0.
	2	4.5	3	2.7	28	4.4	8	6.4	0	0.	9	5.7	19	5.8	84	7.1	17	7.8	0	0.
	0	0.	6	7.7	15	9.4	1	3.0	0	0.	8	12.1	19	10.0	65	8.5	9	9.6	0	0.
	3	9.7	27	14.7	55	14.0	6	18.5	0	0.	3	12.7	13	17.4	37	17.3	6	19.9	0	0.
	6	15.3	30	21.3	56	25.3	11	27.5	1	29.0	3	31.7	4	34.8	4	37.5	1	11.0	0	0.
	3	32.0	23	33.4	31	36.4	5	32.6	3	36.0	0	0.	0	0.	1	40.0	0	0.	0	0.
	1	8.0	2	10.0	2	11.0	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.
	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.
	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.
35D	0	0.	2	4.5	16	6.7	3	7.7	0	0.	0	0.	11	6.4	74	6.2	16	6.8	0	0.
	2	5.5	2	4.5	13	7.2	4	4.0	0	0.	5	5.6	19	6.4	75	6.1	7	6.7	0	0.
	1	4.0	2	10.5	5	7.6	1	10.0	0	0.	6	13.7	20	7.2	35	8.7	6	7.8	0	0.
	1	18.0	7	24.2	9	21.5	1	11.0	0	0.	3	25.3	3	9.7	11	28.2	0	0.	0	0.
	5	32.0	23	29.4	43	26.1	10	44.3	0	0.	0	0.	4	33.8	9	35.0	2	40.0	1	41.0
	1	40.0	6	12.3	6	34.4	3	23.3	1	13.0	0	0.	2	40.0	3	39.3	0	0.	0	0.
	0	0.	3	34.7	3	40.3	1	43.0	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.
	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.
	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.
35E	1	4.0	5	5.2	21	8.9	1	5.0	0	0.	6	8.8	28	7.6	69	7.4	6	6.8	0	0.
	1	16.0	1	3.0	10	4.3	2	8.5	0	0.	2	5.5	14	7.9	52	6.2	5	4.4	0	0.
	1	5.0	8	9.0	6	9.2	0	0.	0	0.	6	10.6	27	10.5	50	9.3	2	14.0	0	0.
	4	22.0	19	19.5	26	19.3	2	32.5	0	0.	4	10.5	22	18.1	22	19.9	5	13.4	0	0.
	6	19.0	37	17.9	31	21.7	0	0.	0	0.	2	40.0	16	33.7	22	37.8	5	32.8	2	23.0
	2	24.0	4	34.2	4	34.5	0	0.	0	0.	0	0.	1	40.0	0	0.	0	0.	0	0.
	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.
	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.
	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.
31V	2	7.0	22	5.3	206	6.0	18	6.7	0	0.	17	7.8	85	7.2	384	7.1	32	7.2	0	0.
	1	2.0	15	7.2	55	7.0	1	20.0	0	0.	11	5.4	79	5.5	215	5.1	22	6.0	0	0.
	4	4.8	21	10.6	37	11.0	4	16.3	0	0.	22	10.0	85	9.1	237	9.2	19	9.0	0	0.
	20	19.1	98	17.4	243	17.5	25	16.1	0	0.	10	20.1	54	23.6	101	24.5	15	24.9	0	0.
	7	16.0	33	18.8	37	19.8	6	21.8	1	34.0	3	28.7	15	26.9	44	28.4	11	30.2	0	0.
	11	24.8	51	35.3	101	34.5	44	31.9	6	31.0	11	37.7	76	41.0	86	41.1	35	41.7	5	52.0
	2	25.5	33	29.3	58	30.2	17	27.2	0	0.	1	43.0	2	41.5	12	45.0	5	40.6	0	0.
	7	29.7	9	32.6	11	28.2	4	30.5	2	43.0	0	0.	0	0.	0	0.	0	0.	0	0.
	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.
34G	0	0.	3	8.3	11	7.4	0	0.	0	0.	4	6.0	18	8.0	15	8.0	1	6.0	0	0.
	0	0.	2	4.5	6	6.8	1	4.0	0	0.	4	7.3	12	3.6	13	6.6	0	0.	0	0.
	0	0.	1	7.0	0	0.	0	0.	0	0.	3	16.[illegible]	12	8.2	9	12.2	0	0.	0	0.
	0	0.	1	8.0	5	10.3	0	0.	0	0.	1	16.1	10	13.4	5	17.0	0	0.	0	0.
	1	17.0	0	0.	2	27.5	0	0.	0	0.	0	0.	1	24.0	2	35.0	0	0.	0	0.
	0	0.	2	26.5	1	13.0	0	0.	0	0.	0	0.	2	39.0	1	37.0	0	0.	0	0.
	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.	0	0.

Table 7-5. Inventory of ESPAWS-Related MOSs.

CURRENT INVENTORY BY PAYGRADE

MOS	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8	E-9	TOTAL
13B	4633	2527	4706	7964	2193	1875	974	5	0	24877
31V	605	209	539	969	490	1965	868	186	0	5831
41C	98	34	53	143	133	85	46	0	0	592
44B	153	106	348	530	470	135	91	1	0	1834
45K	221	105	171	219	222	204	0	0	0	1142
45L	29	31	69	121	127	62	1	0	0	440
63B	4643	2128	4253	7108	4049	1182	8	0	0	23371
63C	1545	823	2821	4357	1642	914	1596	4	0	13702

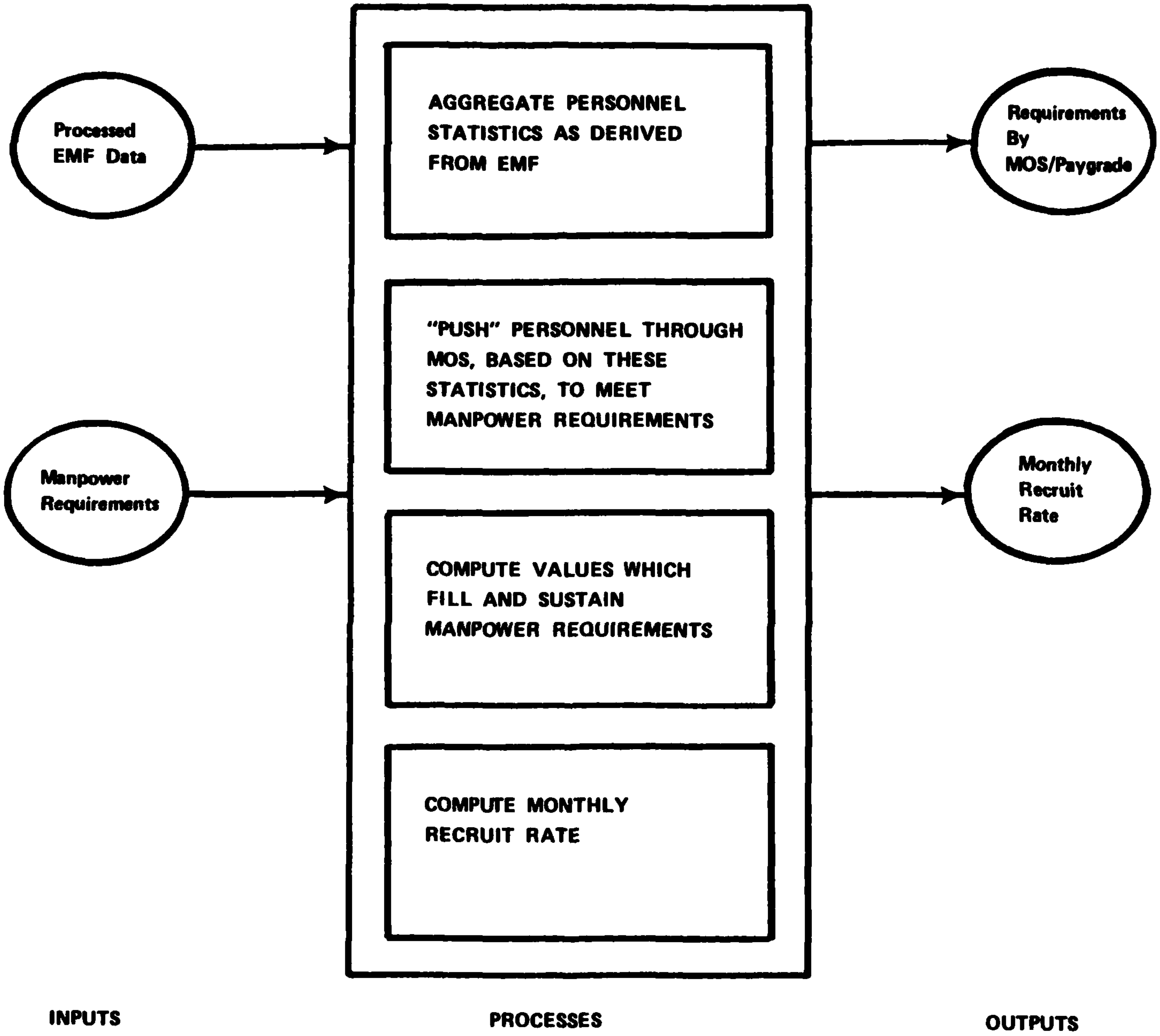


Figure 7-4. Overview of Minimum Flow Solution model.

The MFS model was run using the manpower requirements of the predecessor, reference, and conceptual systems, as determined during manpower requirements analysis (see Figure 7-5). Outputs showing all of the data derived from each execution of the model appear in Appendix B4; a more detailed description of the model is contained in Appendix B3.

The cost of personnel which must be supplied for the predecessor, reference, and conceptual systems was determined by multiplying the manpower requirements by the composite standard rates for military personnel services (TRADOC Resource Factors Handbook, January 1981). The logic behind this costing approach is that:

> It is not feasible to cost total personnel requirements due to the fact that all pipeline (overhead) personnel are part of a pool from which many systems draw. Therefore,
>
> Manpower requirements, which represent the actual hands-on support of the system, are costed for the aggregation of paygrades across all MOSs associated with the SPH at the crew and organizational level.

The bottom line value for each system represents an annual cost to support the specified manpower requirements, based on FY81 rates. (Table 7-6 displays costs by paygrade and total system cost.)

Table 7-6. Manpower Costs

	Predecessor		Reference		Conceptual	
	Manpower Requirements	Cost	Manpower Requirements	Cost	Manpower Requirements	Cost
E-3	5913	68,886,450.	4050	47,182,500.	4212	49,069,800.
E-4	4698	59,890,104.	4455	56,792,340.	3078	39,238,344.
E-5	2349	34,426,944.	3726	54,608,256.	2592	37,988,352.
E-6	2106	36,452,754.	2106	36,452,754.	2106	36,452,754.
E-7	81	1,646,649.	81	1,646,649.	81	1,646,649.
Totals	15147	201,302,901.	14418	196,682,499.	12069	164,395,899.

Figure 7-5. Sample MFS Output.

```
MOS= 13B
OUTPUT TYPE (1,2 OR BLANK) = 1
CAT-PG=
#LEVELS=
REQD= 0,0,5832,3969,1944,1944,81,-1,-1.

MOS-13B   REQUIRES 950.2/MO.

PYGD  REQ.    PERSONNEL
 E1      0.      23582.1
 E2      0.      23881.6
 E3  5832.0      25593.4
 E4  3969.0      11679.7
 E5  1944.0       3585.3
 E6  1944.0       1944.0
 E7    81.0        452.5
```

DESCRIPTION:

INPUTS

MOS – **Military Occupational Specialty**

Output Type – **1: For MFS Output**

2: For advance/attrite input to training step

CAT–PG – **Category and paygrade of sensitization desired**

#Levels – **How many levels to "bleed down" in order to fill a requirement**

REQD – **Manpower Requirements, by paygrade (–1 indicates ignore that paygrade)**

OUTPUTS

REQUIRES – **Recruit rate per month**

PYGD – **Paygrade**

REQ. – **Manpower Requirements**

PERSONNEL – **Personnel Requirements**

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SECTION 8
DETERMINE TRAINING RESOURCE REQUIREMENTS

8.1 OVERVIEW

This section describes the results of the Training Resource Requirements Analysis and outlines the general procedures that were employed in this analysis. A more detailed discussion of the procedures employed in the Training Resource Requirements Analysis is contained in the HARDMAN Methodology Handbook.

Input for the Training Resource Requirements Analysis (TRRA) is provided by the two previous steps in the HARDMAN methodology, the CDB development analysis and the Manpower Analysis (see Figure 8-1). Step 4, the Personnel Analysis, also exchanges information with the Training Resource Requirements Analysis in an interactive fashion by providing overall information on the numbers of people who must be trained. In addition, specific training related data is collected for the Training Resource Requirements Analyses. Output from the Training Resource Requirements Analysis is utilized in the Personnel Analyses in Step 4; the Impact Analysis in Step 5; and the Trade-off Analyses in Step 6.

8.2 ASSUMPTIONS UNDERLYING ESPAWS APPLICATION OF TRRA

The Training Resource Requirements Analysis for the ESPAWS study was completed to (1) determine the applicability of the HARDMAN methodology to the estimation of Army training resources and (2) estimate the resources and costs associated with the training of the crew and organizational maintenance personnel of the ESPAWS self-propelled howitzer (SPH). (No other ESPAWS vehicles were considered.) The following assumptions help to further define the general scope and focus of the TRRA:

> All estimates in the TRRA are based on the best available data, and projections are made from the existing subsystem, courses, etc., which most closely meet the functional requirements of the proposed system.

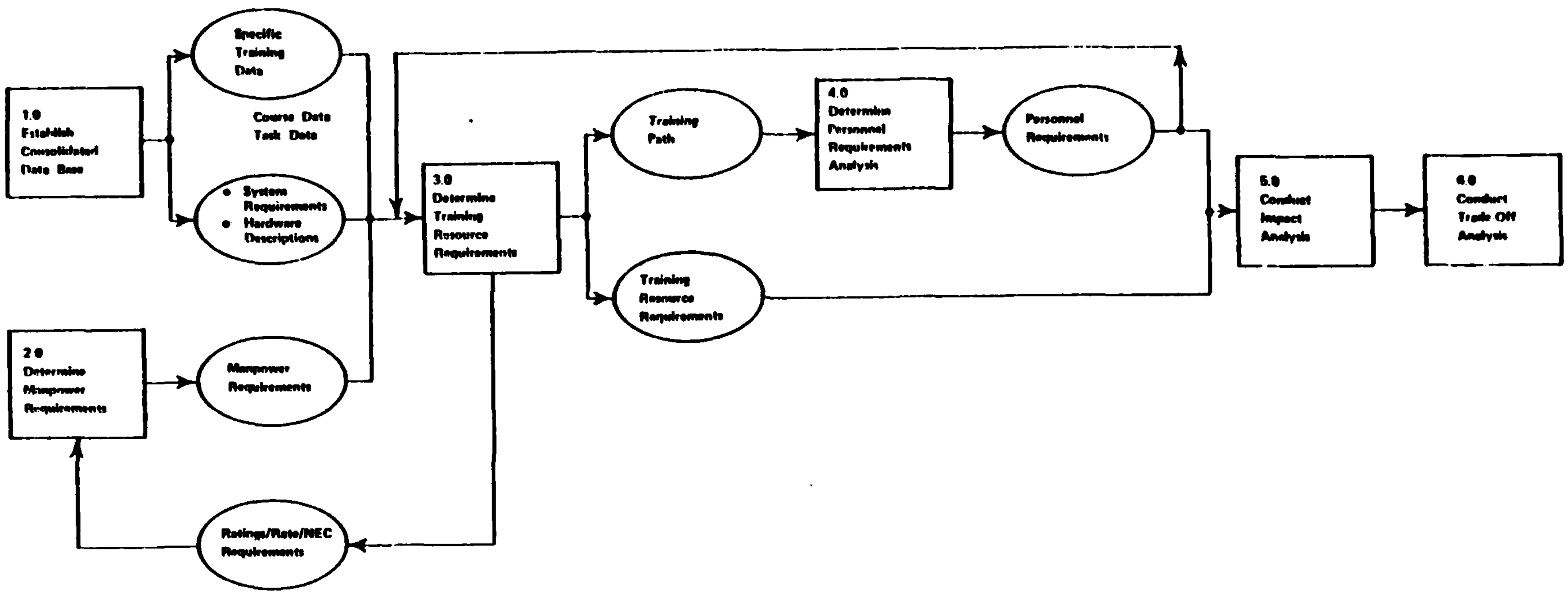

Figure 8-1: STEP 3 (DETERMINE TRAINING RESOURCE REQUIREMENTS) FLOW DIAGRAM[1]

[1]This figure only depicts the major relationships between Step 3.0 and the other steps in the methodology. All possible interrelationships among HARDMAN steps are not depicted.

Training resources and costs are estimated for the "steady-state" or average value year where the "steady-state year" is defined as the first year in which the Army training system is producing replacement training only (that is, all systems have been deployed and training is focused on filling billets vacated through attrition and promotion).

Training associated with the operational test and evaluation of the proposed system and training associated with the initial fielding of the system (e.g., new equipment training) are not estimated.

Only the resources and costs associated with institutional training are estimated in the present version of the TRRA. Training resources and costs associated with unit training are not estimated.[1]

Acquisition costs associated with the development of training products are not estimated.

The TRRA, like the other steps in the HARDMAN methodology, is designed to be applied in an iterative fashion throughout the acquisition process. The results described in this section only describe the initial application of the TRRA to ESPAWS. This initial application is designed to lay the foundation for subsequent applications of the methodology. It is <u>not</u> designed to answer all of the early training estimation questions related to ESPAWS.

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1 An initial attempt was made to develop procedures for estimating unit training resources and costs. However, it was not possible to complete the development of these procedures within the confines of the present study. There were two major problems which inhibited this development effort. First, the Army has no clear-cut policy, at least at the present time, for specifying what the role of various types of training media should play in unit training nor does it have a clear-cut policy for apportioning unit training costs. Secondly, DRC has not yet been able to identify any historical data bases related to unit training costs and resource use.

Related to this point, it is important to note the TRRA initially attempts to estimate costs and resources associated with "first-order" baseline design impacts only. Thus, while the TRRA attempts to estimate the resources and costs associated with the training of the personnel who will operate and maintain the SPH, it does not attempt to estimate training for the instructors who will provide their instruction. Each design impact can be viewed as having a ripple effect with first-order impacts (requirements for the training of individuals who operate and maintain the system) producing second-order impacts (requirements for the training of instructors) and third-order impacts (requirements for the training of training instructors) and so on ad infinitum. Initially, the TRRA only assesses first-order impacts. These first-order impacts produce the bulk of the operational and support costs associated with the system.

The major output of the TRRA is the training program description. Separate training programs are produced for the predecessor, reference, and conceptual systems. Table 8-1 outlines the training program elements that were utilized during the ESPAWS application and lists the appendices containing the data worksheets related to these elements. Each training program contains three major categories of information. The first category of information provides basic descriptive data on the elements of the training concept, individual training paths and associated tasks, skills and knowledges. The second category of information provides estimates of key resources for the courses directly associated with reference/ conceptual system design impacts. Resources are not estimated for courses which are not associated with these impacts (e.g. Non-commissioned Officer Training) during the initial iteration of the methodology. Only total course cost is determined for these courses. The third category describes four different types of training cost measures.

8.3 APPLICATION TO ESPAWS

In the subsections which follow, the results of the application of each substep of the HARDMAN TRRA are described. An overview of the latest version of the substeps in the TRRA is provided in Figure 8-2. Since one of the major purposes of this study is to determine the applicability of the HARDMAN methodology to the Army, the

Table 8-1. Training Program Outline as Applied to the ESPAWS Study. (Adapted from HARDMAN Methodology Handbook)

1.0 Basic Descriptive Data

- **1a** Training Paths – the sequence of courses taken by each MOS associated with the system and the point in the career path an individual is likely to take each course.
- **1b** Training Task Data – a listing of the tasks impacted by the reference/conceptual designs
- **1c** Skills and knowledges – a list of the general skills and knowledges associated with tasks impacted by the reference/conceptual system design.

Related Appendices

APPENDIX C1: Equipment Presentation Formats – pictorial representation of the new and modified equipment.

APPENDIX C2: Task Deletion/Modification and Task Addition Worksheets – a list of the existing system-specific tasks which were modified or deleted to reflect the ESPAWS reference/conceptual designs and the additional tasks which were added to reflect the reference/conceptual requirements.

APPENDIX C3: Task Characteristic Worksheets – a listing of the general skills and knowledges and other modified and additional ESPAWS tasks.

APPENDIX C4: Course Modification/Development Worksheets – detailed listing of modifications in developing ESPAWS related courses.

2.0 Resources

- student billet requirements (replacement personnel)
- instructor requirements[1]
- *training devices*[2]

Related Appendices

APPENDIX C5: Instructor Determination – a listing of the data and procedures used to develop instructor requirements.

3.0 Cost

- individual student cost per course
- average individual training cost
- replacement personnel training cost
- cumulative personnel training cost

Related Appendices

APPENDIX C6: Course Costing Worksheets – a listing of the course costs, replacement training costs, and cumulative personnel training costs by paygrade.

[1] For system-specific courses only

[2] Only the general training device requirements are listed

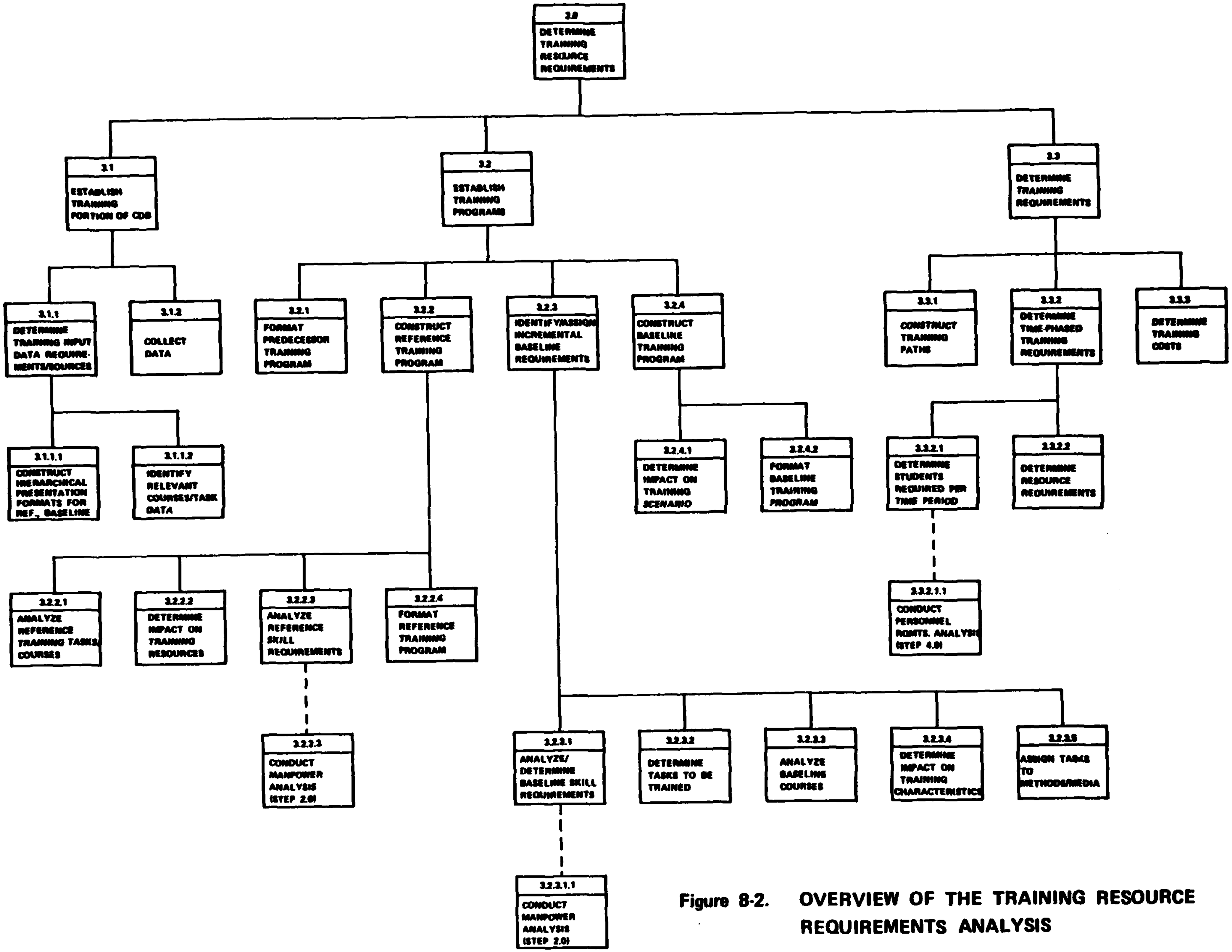

Figure 8-2. OVERVIEW OF THE TRAINING RESOURCE REQUIREMENTS ANALYSIS

availability and relevancy of Army data sources will be discussed as each step of the TRRA is described.

8.3.1 Establish Training Portion of CDB

During this step, the input data requirements for the CDB are determined and specific data elements are collected.

8.3.1.1 Determine Training Input Data Requirements

This step consists of two substeps. During the first substep presentation formats are constructed to represent the predecessor, reference, and conceptual system equipment elements. Existing training data related to the predecessor, reference, and conceptual systems are then identified. The presentation formats (which are shown in Appendix C1) provide a basic communication vehicle for transmitting information between the hardware and training analyst and provide the training analyst with a convenient format for identifying relevant existing courses and associated training information. During the second step, the training data identified in the previous step is collected.

Construct Presentation Formats/Identify Training Data Requirements

The presentation formats for the predecessor and reference system are constructed first. The necessary input for these formats is provided by the predecessor and reference equipment lists which are developed during the equipment analysis in the first step of the HARDMAN methodology. Utilizing the equipment lists, hierarchical block diagrams are constructed for each major functional area of the system. These block diagrams display the structural relationships among the equipment elements. The block diagrams constructed for the SPH predecessor, reference and conceptual systems are shown in Appendix C1. In the predecessor block diagram, each major subsystem is represented by an unshaded ellipse. In the reference block diagram, equipments from the predecessor system are indicated by unshaded ellipses and equipments from other existing systems are indicated by shaded ellipses. (By

definition, the reference system must consist of existing equipments, either from the predecessor or other systems in the DoD/NATO inventory.)

The conceptual presentation format is similar to the reference format with two major changes: (1) equipments which are modifications of reference equipments are represented by circles and (2) "new" equipments (indicating use of an emerging technology) which were not present in the reference system are represented by squares. Existing equipments (that is equipments taken directly from the reference without modification) are again represented by unshaded ellipses (to indicate predecessor equipment) and shaded ellipses (to indicate other existing equipment).

To assist the training analyst in developing a description of the interrelationships among the components of the SPH reference/conceptual systems, an additional presentation format was constructed to represent the flow of information among the major components of the SPH. This information flow diagram is presented in Figure 8-3.

Identify Relevant Data Requirements and Sources

Table 8-2 lists the generic types of data required by the TRRA and the Army data sources from which they can be obtained.[2] Specific data elements within each of these generic data categories are identified utilizing the following procedure. First, up-to-date versions of all generic Army data sources such as DA PAM 351-4, DA PAM 351-20, DA PAM 570-558, DA PAM 310-12, AR 611-201, TRADOC PAM 71-9 are obtained. Secondly, the equipment presentation formats and other data from the equipment analysis in Step 1 of the methodology are examined to identify the equipments associated with the predecessor, reference and conceptual systems. Thirdly, an initial listing of all of the possible MOSs which <u>may</u> be related to the identified equipments is constructed by examining (1) the MOS's currently manning the

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2 The procedures described in this section refer only to Army data sources. It is also possible that equivalent data from other services may be required. The interested reader should refer to the HARDMAN methodology handbook for a description of the Navy data sources which correspond to the Army data sources listed here. A listing of relevant Air Force data sources is presently being constructed.

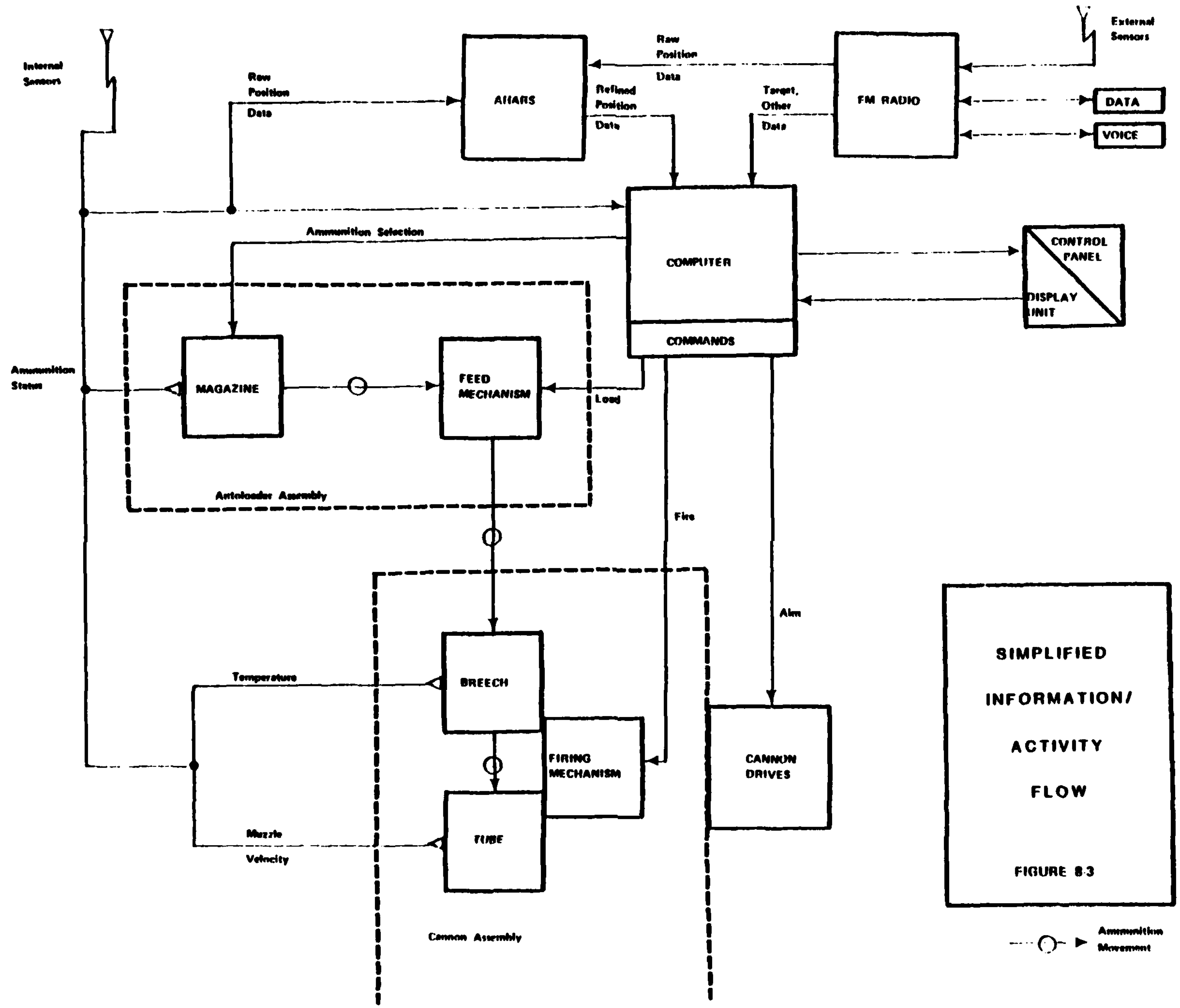
Internal Sensors
Raw Position Data
AHARS
Raw Position Data
Refined Position Data
Target, Other Data
FM RADIO
External Sensors
DATA
VOICE
Ammunition Selection
COMPUTER
COMMANDS
CONTROL PANEL
DISPLAY UNIT
Ammunition Status
MAGAZINE
FEED MECHANISM
Load
Autoloader Assembly
Fire
Aim
Temperature
BREECH
FIRING MECHANISM
CANNON DRIVES
TUBE
Muzzle Velocity
Cannon Assembly
SIMPLIFIED INFORMATION/ ACTIVITY FLOW
FIGURE 8.3
Ammunition Movement

Table 8-2. Training Data Requirements and Related Army Sources.

Data Requirement	Army Data Sources
Task/Skill Data • Task listings broken down by MOS, Skill level, equipment, and assigned training location • Task elements and prerequisite skills and knowledges	*• Enlisted Career Management Fields and Military Occupational Specialties (AR611-201) • Commander's Manual • Soldier's Manual • TMs, FMs • Training Products (SPAs, ETM, job books) • CODAP Questionnaires and Survey Results • ARTEP • Other
Course Data • Course modules with associated hours, media, learning objectives, etc.	*• US Army Formal School Catalog (DA PAM 351-4) *• Army Correspondence Course Catalog (DA PAM 351-20) • Program of Instruction *• Military Occupational Training Cost (MOSB) Handbook • Other
Instructor Determination Data • Instructor contact hours broken down by course modules and associated student instructor ratios • Instructor Manning Procedures Training Device/ETM Data • List and description of available training devices, ETMs, SPAs, etc., and their related applications	• TRADOC Form 377-R for Relevant Couses (DA PAM 570-559) *• Staffing Guide for US Army Service Schools (DA PAM 570-559) *• *Staffing* Guide for US Army Training Centers (DA PAM 570-558)* • Other *• Index and Description of Army Training Devices (DA PAM 310-12) *• Catalog of TASO Training Devices (TRADOC PAM71-9) • Extension Training Material Status List (Quarterly publication) • Other
Training Cost • Training course cost elements • Other training cost elements	*• Military Occupational Specialty Training (MOSB) Cost Handbook • Cost Analysis Program (MOS Training Cost)

* – generic Army data source which the training analyst should have on hand before the analysis begins.

equipments in the predecessor and reference system and (2) the MOS descriptions listed in AR 611-201. Fourth, the general courses in the training paths of the identified MOSs are identified by examining the MOS training paths listed in the Military Occupational Specialty Training Cost Handbook. Fifth, system-specific courses relating to the specific equipments in the predecessor reference and conceptual systems are identified by examining the various Army course catalogs and by interviewing the training staff at the school(s) associated with the predecessor, reference, and conceptual equipments. (These interviews will help identify courses currently under development). Sixth, an initial list of relevant training devices/Extension Training Materials (ETMs) is constructed by examining DA PAM 310-12, TRADOC PAM 71-9, and the ETM status list, corresponding data sources from other services, and current training device literature, and, if necessary, by interviewing (1) the training staff at the schools associated with the predecessor, reference, and conceptual equipments, (2) the staff of the Project Manager, Training Devices (PM TRADE) (3) the staff at the Army Training Support Center (ATSC).

8.3.1.2 Collect Data

During this step, all of the specific data elements identified in the previous step are collected. Apart from the logistical problems associated with ordering data (these will vary depending on the status of the organization with which the training analyst is associated), the collection of data should be fairly straightforward. The one exception is the collection of CODAP data. To obtain the appropriate CODAP data, the training analyst must first obtain the CODAP questionnaire booklets for the MOSs in which he is interested. The analyst must then determine the specific questions on which he would like to obtain survey data and then order the data associated with these questions from CODAP. It should be noted that DRC experienced great difficulty in obtaining CODAP survey data results. In fact, at the time this report was completed, data still had not been received and hence were not used in the analyses. The CODAP data is not critical but could provide relevant data on the frequency with which tasks are currently being performed. Future applications of the methodology must examine why the delays in obtaining CODAP data occurred.

Apart from CODAP, the availability of the data elements seemed to be adequate for conducting the TRRA; however, lack

of a centralized storage location for many of the data element delayed the analyses. The development of a centralized location for those data items could greatly facilitate the analyses. Also, it should be noted that all data requests were treated as a one-time event. Future efforts must examine the impacts of large numbers of data requests on the resources of the associated Army organization. A description of the quality of the individual Army data elements is provided in the conclusions in Section 9.6.

8.3.2 Establish Training Programs

During this step, the predecessor and reference training programs are constructed and formatted, the effects of the conceptual design impacts are determined, and the conceptual training program is constructed. More details on this step are provided below.

8.3.2.1 Format Predecessor Training Program

During this step, the training data collected for the predecessor system (i.e., the M109A1) are placed in formats which will allow for later comparison with the reference and conceptual systems.

8.3.2.2 Construct Reference Training Program

This step is broken down into four substeps (see Figure 8-2).[3] During the first substep, tasks currently being performed on the predecessor system are examined and modified to reflect differences between the predecessor and

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3 The order of the steps listed in this section of the report is slightly different from the order of the steps listed in the HARDMAN Methodology Handbook (substeps two and three have been interchanged). The order listed in this report reflects the most current version of the TRRA.

reference subsystems and additional tasks are added to reflect the new reference system requirements. During the second step the skills and knowledges associated with the modified/additional tasks are determined and the reference MOS/skill level assignments are finalized. (This step is conducted in an interactive fashion with the Manpower Analysis.) During the third step, reference training courses are modified and constructed to reflect the tasks, skills and knowledges identified in the previous step. During the fourth step, the reference training program data are placed in the standard training program format.

Analyze Tasks Related to Reference Equipment.

This step begins by reexamining the tentative list of SPH related MOSs which was constructed as part of the data identification step in Section 8.3.1.1. This list describes all of the MOSs which might have some involvement with the projected system (the final list of reference MOSs will be determined in the fourth substep). Once identified, the Commander's Manuals for each of these MOSs are examined to identify any tasks directly related to the predecessor (the M109/series howitzer), and any other existing reference equipment currently being utilized by Army personnel. The training analyst, working together with the hardware analyst and utilizing the presentation formats and all available descriptions of the reference equipment, must then examine each of the system specific tasks related to the existing Army equipment and identify: (1) which tasks must be deleted to reflect the reference system requirements and (2) which tasks must be modified to reflect the reference system requirements. (Listings of all of the tasks currently being performed by an MOS are provided in the commander's manual for that MOS). The resulting system-specific task changes are then documented in a series of worksheets which describe the type of task deletion or modification and additional task-related information such as the initial skill level for which the task is currently trained; the current initial and advanced training locations for the task; and the equipment subsystem associated with the task. (The task deletion/ modification worksheets used during the ESPAWS study are listed in Appendix C2.)

Table 8-3 displays the different types of task deletions and modifications that were conducted during the study and their associated identification codes. Tasks associated with three of the task modification types (REL, SKI, and MAJ) are examined in greater detail in the next substep, analysis of reference skill requirements. These additional analyses are

Table 8-3. Task Deletion/Modification Codes.

Task Deletion

Code	Description of Reason for Deletion
ELI	Elimination of Subsystem
AUT	Task Automation
MTBF	Increase in MTBF
MP	Change in Maintenance Policy
O	Other – (Must be specified)

Task Modification

Code	Description of Type of Modification	Requires Task Characteristic Worksheet
NC	No change in system-specific task	No
MIN	Minor task modification—task essentially the same. Only minor changes in equipment/nomenclature required.	No
REL	Frequency change – same task but task is performed more (less) frequently due to change in reliability.	Yes
SKI	Skill level change – task essentially the same but assigned to different skill level.	Yes
MAJ	Major task modification – significant change in skills and knowledges and/or other task characteristics (e.g., difficulty, importance).	Yes

documented in a series of task characteristic worksheets. The MIN tasks are not analyzed further since it is assumed that their skill and knowledges and associated task characteristics will be equivalent to the skills and knowledges associated with the existing task.

Once the tasks associated with existing Army equipments have been modified, requirements for additional reference system tasks are identified. The additional tasks are required for each of the non-Army subsystems included in the reference subsystem. During the ESPAWS study, three non-Army subsystems were added to the reference system; the land navigation system (derived from the Navy AN/ASN-107), the ballistics computer (derived from the Navy AN/ASQ-155), and the autoloader (derived from the Navy MK-42 MOD 10). Development of the additional tasks was again accomplished by a team composed of both training analysts and hardware analysts. Input for the identification of additional tasks was provided by (1) the equipment presentation formats, (2) description of the non-Army hardware and (3) descriptions of the tasks associated with this non-Army hardware from non-Army data sources (e.g. Navy task descriptions.)

The additional tasks identified for the SPH are documented in a series of worksheets listed in Appendix C2. Each of these worksheets lists the additional task and describes the initial skill level at which the task is trained (determined in the second substep of this step), the initial and advanced training locations at which the task is estimated to be taught (determined in the third substep in this step); and the number of the task characteristic worksheet associated with the task, along with similar information for the comparable task (preferably an Army task) which most closely approximates the skill and knowledge requirements of the additional task.

In developing the task statements for the additional tasks, DRC initially attempted to utilize a standardized set of action verbs. However, this approach was abandoned when the types of action verbs utilized in the Commander's and Soldier's Manuals were examined. At the present time, there is a great deal of variation in the task descriptions found in these manuals both in terms of the different types of action verbs employed and in their level of specificity. For these reasons, DRC felt that it was not wise to employ a standard set of action verbs which might conflict with the types of action verbs utilized by the individual schools. However, it was felt that additional attempts to develop a standard set of action verbs should be undertaken in future research efforts since the benefits of such an approach are

obvious (greater opportunity for cross-school comparison, greater capability for computerizing task descriptions and greater opportunity for using systematic training tools).

Table 8-4 summarizes the types of task modifications that were made to existing Army tasks and the additional tasks which were required for the SPH reference system. (The procedures for assigning the modified/additional tasks to individual MOSs is described in the next substep.)

Analyze Reference Skill Requirements

During this substep, the skills, knowledges and other task characteristics associated with the modified and additional tasks identified in the previous step are determined and the assignment of reference MOSs and skill levels is finalized.

The detailed assessment of task characteristics conducted in this substep is only undertaken for (1) the additional tasks which were added to the reference subsystem for non-Army tasks and (2) the tasks associated with significant task modifications (that is, the tasks indicated by the MAJ, REL and SKI task modification codes in the previous step.) Figure 8-4 displays the types of tasks selected for task characteristic analysis. The characteristics of all the tasks not selected for this analysis are assumed to be equivalent to their present Army task.[4]

Appendix C3 describes the task characteristics worksheets which were developed for the ESPAWS study. Two types of task characteristics worksheets were employed. One type was used to describe the characteristics of the REL and SKI type tasks. The REL tasks are existing Army tasks which only require a change in task frequency; no changes in any of their other task characteristics (e.g., skills and knowledges) are required. Similarly, the SKI tasks only require a change in skill level (such a change, for example, might be required to reflect a change in manning policy); no changes in any of their other task characteristics are required.

No SKI type tasks were identified during the ESPAWS study. However, several-REL type tasks indicating changes in task

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4 This assumption can be modified on subsequent iterations of the methodology.

Table 8-4. Summary of Reference Task Modifications/Additions.

	Reference				
MOS	AUT	MIN	REL.	MAJ	ADD
13B	2	46	22	16	4
(45D)*	–	–	–	–	6
31V	0	0	0	0	13
41C	0	0	11	0	0
44B	0	0	0	0	0
45K	0	10	0	0	0
45L	0	18	0	0	10
63B	0	0	0	0	0
63C	0	9	0	0	0
Total	2	83	33	16	33

Task Deletions: AUT – Automation Task Deletion

Task Modifications: MIN – Minor Task Modification required

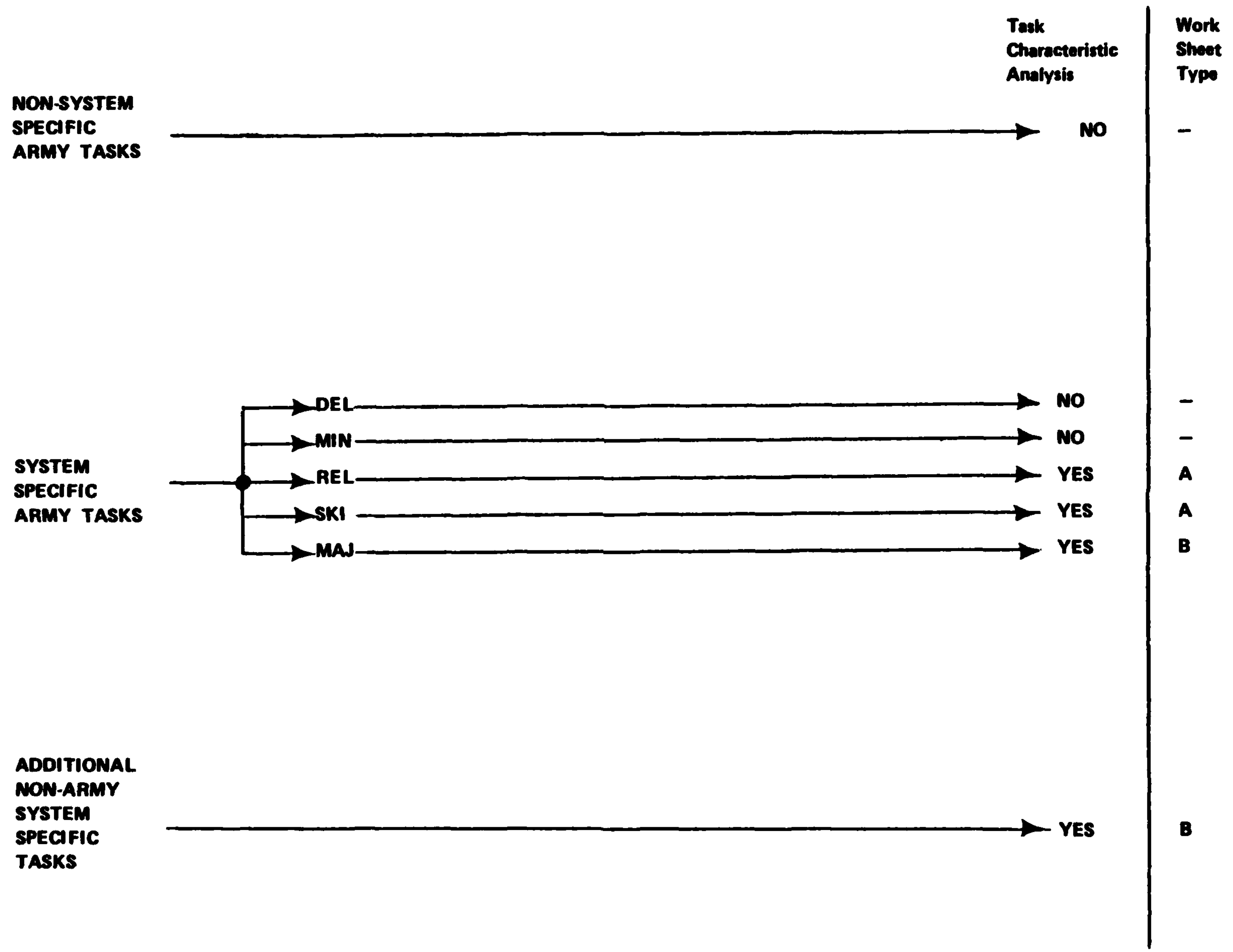
REL – Change in Task Frequency; otherwise Task Essentially the Same

MAJ – Major Task Modification Required

Task Additions: ADD. – New, Additional Task Required

*Complete task listing for 45D not yet available. Thus, only additional tasks are listed. 45D is new MOS as of October 1980. Previously it was 13BU6.

Figure 8-4. Task Types Selected for Task Characteristic Analysis.



frequency were required for both the SPH reference and conceptual systems. These changes in task frequency were needed to reflect (1) changes in equipment reliability and (2) the decreases in frequency of certain tasks which are currently performed manually. The latter changes in task frequency are primarily associated with the tasks related to gun orientation and loading. These task areas will be automated in the SPH. Because the REL tasks only impact frequency and do not change the skills level/knowledges associated with the task, a much less detailed analysis of their task characteristics is required. The worksheets for all REL type tasks utilized during the ESPAWS study are listed in Appendix C3 (these worksheets are labelled "worksheet A"). Each of these worksheets lists the task number, the existing frequency with which the task is performed, the new frequency with which the task will be performed, the estimated difficulty of the modified task, the estimated importance of the modified task, and the initial and advanced training locations for the modified task (these locations are determined in the next substep).

The task characteristic worksheet used to describe the additional tasks or the existing tasks associated with major modifications (labelled "Worksheet B") lists the same information as the worksheets used for the REL tasks (the task characteristic "A" worksheets). However, they also (1) list information on the support equipment/tools associated with each task, (2) list similar information for the comparable task which is most similar to the modified/ additional task, and (3) provide a detailed listing of the skills and knowledges estimated to be required for the new task.

Determination of the skills and knowledges associated with a modified/additional task is determined by first identifying the skills and knowledges associated with the comparable task and then adding or deleting items to reflect the projected differences betwen the modified/additional task and the comparable task.

Estimates of task difficulty, importance, frequency, and duration for a modified/additional task are developed by first constructing estimates for the comparable task and then modifying these values (where necessary) to reflect the

differences between the modified/additional tasks and the comparable task.[5]

Input for the determination of skills and knowledges and the assignment of task parameter values is provided by (1) all available descriptions of the skills, knowledges, and task elements of the comparable task, (2) course/ instructional material related to the comparable task, and (3) descriptions of the reference system hardware.

Once all the skills and knowledges for the modified/ additional reference system tasks have been identified, these tasks can be assigned to MOSs and skill levels. The MOSs and skill levels for all other tasks are assumed to be identical to their existing MOS/skill level assignment. Of course, on subsequent iterations of the methodology, alternative MOS/skill level assignments can be examined.

The assignment of MOSs to the modified/additional tasks is accomplished by first determining if one of the MOSs currently performing the other unmodified tasks could be assigned any of the modified/additional tasks.[6] This is done by comparing the skills and knowledges of the MOSs already associated with the unmodified tasks (as described in the soldier's manual and the POI for the AIT course associated with those MOSs) with the skill and knowledge requirements of the modifed task.

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[5] Values on other task parameters beside difficulty, importance, etc., could also be assessed at this time. The parameters described above were assessed because they were intended to be used as input for the training algorithms used in subsequent steps. However, these algorithms were not employed in this iteration of the methodology. At any rate, if a different set of training algorithms is employed, a different set of task parameters would have to be assessed during this substep.

[6] The term "modified task" in the remaining subsections of this section refers only to the MAJ and REL task types. The, term does not include the MIN type tasks which only involve minor task modifications.

If one of the existing reference MOSs cannot be assigned the task, the skills and knowledges associated with the task must be compared with the general descriptions of MOS skills and knowledges listed in AR 611-201 and the MOS should be assigned to the task which (1) most closely resembles the skill requirements of the task and (2) is likely to be assigned to the mission area in which the projected system will be employed.[7]

Skill levels for the modified/additional tasks are determined by identifying a comparable task currently being performed by the assigned MOS, which is similar in estimated complexity, difficulty, and associated skills and knowledges to the modified/additional task. Then assign the skill level associated with this comparable task to the modified/additional task.

Once identified, the MOS/skill level assignments are presented to the manpower analyst who examines them from the perspective of manpower loading, workload categories, etc. The manpower analyst may then recommend changes based upon this additional analysis. (A description of the assignment of MOS/skill level from the perspective of the manpower analyst is described in Section 6.) When the manpower analyst has completed his examination, the reference MOS/skill assignments can be finalized, and these assignments can then be noted in the appropriate places in the task-related worksheets.

Table 8-5 lists the MOSs which were selected for the SPH reference system. The Field Artillery Mechanic MOS (45D) is a new MOS which has not been completely implemented. This MOS will take over the duties currently being performed by the ASI-13BU6. Because the POI for 45D was obtained in the

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7 The latter restriction is necessary because an MOS may have skills and knowledges very similar to the proposed task, but be unlikely to be assigned to the task because of the overall mission area to which the MOS is usually assigned. For example, at a general level, the Avionics Navigation Equipment Repairman (35M) more closely resembles the task requirements associated with the SPH land navigation system than does the Tactical Communications Systems Operator (31V). However, 35M is unlikely to be assigned to field artillery; hence, the SPH tasks related to the land navigation system were assigned to 31V rather than to 35M.

Table 8-5. Reference MOS.

13B	Field Artillery Crewman
45D (13BU6)	Field Artillery Turret Mechanic
31V	Tactical Communications System Operator/Mechanic
41C	Fire Control Instrument Repairman
44B	Metalworker
45K	Tank Turret Repairman
45L	Artillery Repairman
63B	Power Generation and Wheeled Vehicle Mechanic
63C	Track Vehicle Mechanic

later phases of study, the tasks originally assigned to 13BU6 were reassigned to 45D and the POI for 45D was then modified to reflect these changes. However, in the manpower and personnel analysis, the 13BU6 designation was still employed and all references to 13BU6 manpower and personnel requirements can be interpreted as direct requirements for 45D.

Determine Impact on Training Courses

During this substep, the modified/additional reference tasks are assigned to training locations and courses are modified and/or constructed to reflect these modified/additional reference tasks.

Determination of the impact on courses begins by determining which of the modified/additional tasks must be trained. Originally, DRC attempted to determine the tasks to be trained by utilizing the Difficulty-Importance-Frequency (D-I-F) algorithm which is described in the HARDMAN handbook. But in testing this algorithm by applying it to current Army tasks, DRC found that this algorithm was not making task assignments which were congruent with the existing Army assignments. However, it was soon determined that the determination of the tasks to be trained was irrelevant given the wide range of training locations typically specified in the Commander's Manual (see Table 8-6). This range was so broad that it was hard to imagine a task which would not be assigned to at least one of the listed training locations. The DIF algorithm emphasizes the identification of formal school training requirements. Thus, the "no training" category in the DIF algorithm had included most of the training locations listed under unit training. Hence, it was finally determined that the DIF algorithm would not be used and that the question of determining the tasks to be trained could be totally encompassed by the larger question of assigning tasks to training locations.

Training locations for the modified/additional tasks were determined by first identifying comparable tasks within each MOS which most closely resembled the skill and knowledge requirements of the modified/additional tasks. The training locations associated with this comparable task were then

Table 8-6. Types of Training Locations Typically Listed in Commander's Manuals*

Institutional
Basic Training
AIT/OSUT
Primary NCO
Basic NCO
Advanced NCO
Sergeant Majors Academy
Service School (System Specific Courses)
Primary Leadership Training
Primary Technical Training
Basic Technical Training
Unit
Scheduled OJT
Self Study
Scheduled Training
Training Extension Course/Correspondence

*Utilization of these categories varies across schools.

assigned to the projected task.[8] Two types of training location assignments were made for each modified/additional task -- an initial (or qualifying) training location indicating when the skills associated with the task will first be learned, and an advanced (or remedial) training location indicating where additional proficiency in the task will be achieved.

Once the modified/additional tasks have been assigned to training settings, the existing institutional training courses related to these training settings can be modified and, where necessary, new courses can be developed to reflect the additional task requirements.

Modification of the existing courses is achieved by first identifying the existing courses associated with modified/ additional tasks. The program of instruction for these existing courses are then examined to identify the objectives/ subject matter areas covered in each course module. These subject matter areas are compared with the tasks and skills which were added, modified, or deleted during the previous substep. Those general skill areas in the existing courses which are no longer needed for the reference system are identified first and the modules associated with these skill areas are eliminated. New general skill areas, which must be added to the existing courses to reflect the modified/additional skill requirements, are then identified and these modules are added to the reference course outlines.

Once the course modules have been developed, the instructional method to be utilized with each module is determined. Table 8-7 lists the types of instructional methods that are available for use with Army courses. Instructional methods for each modified/additional course module is determined by first identifying a comparable course module, which involves the same type of tasks and skills as the modified/additional module. The type of

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8 An initial attempt to develop a more quantitatively-based algorithm for assigning tasks to training settings failed because DRC was unable to clearly identify the Army policy for assigning tasks to training settings. Army policy in this area appears to be in a state of flux. It was not possible to unravel these policy issues within the confines of the present study.

Table 8-7. Army Training Methods and Associated Student/Instructor Ratios*

Methods	S/I Ratios
PE1 — hardware oriented (hands-on) practical application.	6:1
PE2 — nonhardware oriented (nonclassroom) practical application	6:1
PE3 — classroom practical application	20:1
SP — self-paced instruction	20:1
E2 — nonhardware performance examination	6:1
E1 — nonhardware performance examination	6:1
E3 — written examination	1 per class
C — conference/lecture	1 per class
D — demonstration	20:1
F — film	1 per class
TV — television	1 per class
CAI — computer assisted instruction	20:1
PI — programmed instruction (using programmed text)	20:1
S — seminar	20:1
CS — case study	20:1
EL — *elective (in-house only, except for CGSC)*	1 per class
GS — guest speaker	1 per class
DF — dual flight hours (only aviator courses) (do not *include in ICH computations)*	—
SF — solo flight hours (only aviator courses) (do not include in ICH computations)	—

*Taken directly from DA PAM 570-588, *Staffing Guide for US Army Service Schools.*

instructional method specified for the comparable module is then assigned to the modified/additional module.

With the method for each module determined, the curriculum hours to be devoted to each module can be determined. Here again, comparable course modules are identified and their curriculum hours are examined. Discrepancies between the existing course module(s) and the modified/additional course module are identified and the existing module hours are adjusted accordingly. This adjusted figure is then used as an estimate of the curriculum hour requirements for the modified/additional module.

The procedure for constructing new courses is similar to the procedure for modifying existing courses with the following exceptions: (1) identification of comparable modules is more likely to require taking modules from several different courses rather than just a single course; and (2) modules from non-Army courses may have to be utilized as comparable data. Whenever a module from a non-Army course is utilized, the training analyst must exercise special care in estimating the curriculum hours as differences between the entering skill levels of the Army and non-Army personnel must be accounted for.

Table 8-8 displays the modified and additional courses which were constructed for the SPH reference system. Worksheets documenting the module modifications and additions associated with these courses are listed in Appendix C4.

Once the courses have been constructed, the media associated with the reference training can be determined. During the initial iteration of the methodology, only general requirements for major training devices are determined, since these devices are the major drivers of media-related training costs. On subsequent iterations of the methodology, requirements for other less expensive media types (e.g., SPAs) can be determined.[9]

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9 Procedures for making these more detailed media assignments must be developed. Again, these procedures will be hindered by the lack of a clear-cut policy regarding the use of different types of media in the Army. This is particularly true for the SPAs/ETM media. Development of appropriate procedures will require sorting out the available Army policy in this area.

Table 8-8. Modified and Additional Courses Developed for ESPAWS

Modified Courses:

Course No.	Title	Length*	MOS
041-13B10	Field Artillery Crewman	12.5 (12.4) weeks	13B
643-45D10	Field Artillery Turret Mechanic	5.2 (4.8) weeks	45D (13BU6)

Additional Courses:

Course No.	Title	Length	MOS
101ASIX1	ESPAWS Computer	1.89 weeks	31V
101ASIX2	ESPAWS Land Navigation System	2.8 weeks	31V
642ASIX1	ESPAWS Autoloader	3.4 weeks	45L

*Existing course length in parentheses.

Since no difference was projected between the major training device requirements associated with the SPH reference and conceptual systems, discussion of the reference training device requirements and the procedures used to develop them have been combined with the discussion of the conceptual system training device requirements in Section 8.3.2.3, they are not repeated here.

Format Reference Training Program

Once all of the individual reference training program elements have been developed, they are placed in standard formats to facilitate the reporting of the study results.

8.3.2.3 Identify Incremental Conceptual System Requirements

During this step, the effects of the conceptual system design impacts on the reference tasks and training program are estimated and applied, and the baseline training program elements are developed. This step consists of five substeps. These five substeps are described in the sections which follow.

Analyze/Determine Conceptual Skill Requirements

This substep begins by identifying the reference system tasks which must be modified to reflect the conceptual system design differences and the additional tasks, which must be added to the reference system tasks to reflect these same design differences. (A detailed description of these design differences was presented in Section 5.)
The procedures used to construct the modified/additional conceptual system tasks are identical to the procedures used to construct the modified/additional reference tasks -- the only change being that reference-conceptual equipment differences rather than predecessor-reference equipment differences are utilized as input.

Table 8-9 displays the modified/additional tasks which were required for the SPH conceptual system. As Table 8-9 indicates, no additional tasks, over and above the reference system tasks, were required for the SPH conceptual system. In addition, the only task modifications required were REL-type task modifications (i.e., changes in task frequency) and these frequency changes were only required for thirteen

Table 8-9. Conceptual System Task Modifications/Additions

MOS	AUT	MIN	REL	MAJ	ADD
13B	0	0	3	0	0
(45D)*	–	–	–	–	0
31V	0	0	0	0	0
41C	0	0	0	0	0
44B	0	0	0	0	0
45K	0	0	1	0	0
45L	0	0	3	0	0
63B	0	0	0	0	0
63C	0	0	6	0	0
Total	0	0	13	0	0

Task Deletions	AUT – Automation Task Deletion
Task Modifications	MIN – Minor Task Modification Required
	REL – Change in Task Frequency; Otherwise Task Essentially the Same
	MAJ – Major Task Modification Required
Task Additions	ADD. – New, Additional Task Required

*Complete task listing for 45D not yet available. 45D is a new MOS as of October 1980. Previously it was 13BU6.

tasks. The small amount of task modification/addition required for the conceptual system was due to the fact that conceptual design differences only changed the reliability, and not the maintainability or operability, of equipment components. Hence, only changes in task frequency of the tasks related to these reliability changes, were needed to reflect the conceptual design differences.

The REL tasks related to conceptual design differences are identified in the reference task deletion/modification and task addition worksheets listed in Appendix C2 by the task characteristic worksheet numbers associated with tasks. Tasks impacted by the conceptual design have a "C" in the middle element of their task characteristic number (i.e., XXX-C-X).

The elements in the task characteristic worksheets for the modified conceptual system tasks are determined utilizing the same procedures which were employed for the modified/additional tasks in the reference system. The task characteristic worksheets for all the SPH conceptual system REL tasks are contained in Appendix C2. (No other conceptual system tasks required a task characteristic analysis.)

Once the conceptual system task and task characteristics have been determined, the conceptual system MOS and skill levels can be determined utilizing the same procedures used to determine the reference MOS/skill levels. Because the SPH conceptual system only involved REL tasks, and these REL tasks only involved minor changes in task frequency (as measured by the frequency scale used in this analysis), no changes in MOS/skill level assignments were required for the SPH conceptual system.

Determine Tasks to be Trained

As noted above, determination of the tasks to be trained can be encompassed under the more general problem of assigning tasks to training settings/locations (when one utilizes a wide range of training settings such as self-study and supervised OJT, etc.). The procedures used to assign modified/conceptual tasks to training settings are identical to the procedures used to assign the modified/additional reference system tasks to training settings. Because the SPH conceptual design differences only impacted the frequency of a small number of tasks, no changes in the reference task training setting assignments were required for the conceptual system training program. (All conceptual

Table 8-10. Candidate List of Major Training Device Requirements Associated with ESPAWS Howitzer Crew and Organizational Maintenance

Training Device	Operator/ Maintainer	Type	Description	Comparable Devices
ESPAWS Electrical/ Hydraulic Systems Maintenance Trainer	Maintainer	Two-dimensional (2D) Programmable	Provides training in the proper troubleshooting procedures for the ESPAWS electrical/hydraulic systems for both organizatinal and DS/OS personnel.	M60A1/A3 Tank Programmable Trainer
ESPAWS Autoloader Maintenance Trainer	Maintenance	Three-dimensional (3D) Programmable	Provides training in funtional testing, inspection, and removal/replacement of selected components of the ESPAWS autoloader	Army Maintenance Training and Evaluation Simulation System (AMTESS)
ESPAWS Crew Trainer	Operator	Embedded Crew Trainer	Provide ESPAWS crew training for indirect fire missions including tasks related to orientation, and firing.	No devices are exactly comparable. But device may include features similar to both the M60A2 conduct of fire launcher trainer (minus the visual effect simulator) and systems with more of an emphasis on software-related implementation such as the Patriot Command Station Trainers.
ESPAWS Howitzer Driver Trainer	Operator	3D Simulator	Provide training for the driver of the ESPAWS Howitzer over a wide range of environments and driving conditions.	XM1 Tank Trainer; Track Vehicle Driver Trainer; M60 Series Tank Driver Trainer
ESPAWS Direct Fire Trainer	Operator	(1) Laser-mounted Target (2) Laser-towed Target	Provide ESPAWS crew training for direct fire missions.	1) Multiple Integrated Laser Engagement System (MILES) 2) Field Artillery Direct Fire Trainer-Laser
ESPAWS Computer Operational Check and Fault Isolation Software	Operator/ Maintainer	Completely Embedded Software	Provide training in the operational check and fault isolation of the ESPAWS computer.	Many existing military embedded software systems have this capability.

system training setting locations are marked in the appropriate places in the task-related worksheets.)

Analyze Conceptual System Course Impacts.

The procedures used in modifying existing courses or in constructing additional courses to reflect conceptual design differences are identical to the procedures used in modifying/developing the reference system courses. However, because the SPH conceptual design differences had small, insignificant impacts on the reference tasks and their associated task characteristics, it was not necessary to make any changes in the courses developed for the reference system.

Assign Tasks to Methods/Media

During the initial iteration of the TRRA, only general requirements for major training devices are determined, since these devices are the major drivers of media-related training costs. On subsequent iterations of the TRRA, requirements for other, less expensive media types can be identified. These more detailed media assignments can be made by using a series of algorithms to assign each of the modified/additional tasks to a specific media type.[10]

Table 8-10 displays the general requirements for major training devices which were identified for the SPH reference and conceptual systems. (No differences in training device requirements were projected between the reference and conceptual systems because of the small task differences associated with these systems.) For each type of training device requirement identified, Table 8-10 lists the type of personnel to be trained with each device (operator/maintainer); the type of device (where two different types of device options seem viable, both are listed); a description of the use of the device; and a brief listing of the existing devices which display some of the features needed for the projected device.

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10 As was noted in Section 8.3.2.2, construction of the appropriate media selection algorithms for detailed media assignment was not completed in the present study because of the difficulties associated with unraveling the present Army policy relating to media assignment.

Again, it is important to note that Table 8-10 is only intended to identify the general requirements for training devices. The final determination of training device requirements cannot be completed until (a) the SPH hardware systems have been specified in greater detail, and (b) the staff at the appropriate schools and PM TRADE have had a chance to review and evaluate the initial list of training device requirements.

8.3.2.4 Construct Conceptual Training Program

During this step, the baseline training program elements are placed in standard formats to facilitate the reporting of the study results.

8.3.3 Determine Training Requirements

During this step, the training program elements determined in the previous steps are multiplied by the yearly personnel requirements to determine overall training cost and resource utilization for the steady-state condition.

The step is broken down into three basic substeps. During the first substep, training paths are developed to represent the sequence of training courses taken by personnel in the predecessor, reference, and conceptual systems. During the second substep, the number of personnel in each MOS/skill level requiring training per year is determined along with the yearly resource requirements for the other training resources. In the third substep, the yearly resource requirements are multiplied by the appropriate cost factors to determine yearly training costs.

8.3.3.1 Construct Training Paths

During the Navy version of the TRRA, diagrams are constructed during this step to represent the training paths of individual ratings (MOSs) in the predecessor, reference, and conceptual systems. However, the training paths associated with the SPH were straightforward (that is, the paths did not require complicated branching). Hence, it was

felt a simple sequential listing of the SPH training courses would be sufficient. Such a listing for each of the SPH-related MOSs is provided in Table C5-3 in Appendix C5.[11]

Skill level assignments for the new/additional courses listed in Table C5-3 were made by examining the skill level assignments made in Sections 8.3.2.2 and 8.3.2.3. Skill level assignments for other existing courses were taken directly from the MOS Training Cost Handbook.

8.3.3.2 Determine Time-Phased Training Requirements

During this step, yearly training resource requirements for the steady-state year are determined for the predecessor, reference, and conceptual training systems. The steady-state year is defined as the first year in which the Army training system is producing replacement training only. (That is, all systems have been deployed and training is focused on filling billets vacated through attrition and promotion.)

This step is broken down into two substeps. During the first substep, the number of replacement personnel to be trained is determined. During the second step, the training resources needed to produce the number of replacement personnel identified in the previous step is determined.

Determine Students Required Per Time Period

During this substep, the number of students required to be trained in each course is determined. This substep interacts with the Personnel Analysis. As a result of the Personnel Requirements Analysis, the personnel analyst provides feedback information to the training analyst on the attrition rates and promotion rates associated with each MOS. These rates, along with the manpower requirements developed in Section 6, are then entered into an algorithm which determines the number of personnel in each skill level

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11 Leave and Administration costs associated with AIT are listed in these tables, since these figures were readily available from the MOS Cost Training Handbook. Of course, there are no courses associated with these cost elements.

Table 8-11. Replacement Personnel Algorithm.

Replacement personnel for the Kth skill level, $NREP_K$, is determined by the following equation.

$$NREP_K = \sum_{i=1}^{N} NREP_i$$

where:

N = the number of paygrades within the skill level, and $NREP_i$ is the number of replacement personnel within the i th grade.

$NREP_i$ is defined as follows:

$$NREP_i = REQ_i \times LOSS_i$$

where:

REQ_i is the manpower requirements at the ith paygrade; and the percentage of *requirements*, $LOSS_i$, that must be replaced per year, is defined as follows:

$$LOSS_i = \frac{ATT_i}{AYEAR_i} + \frac{UP_i}{AYEAR_i}$$

ATT_i = attrition rate for the ith paygrade

UP_i = upgrade rate for the ith paygrade

$AYEAR_i$, the average length service for $paygrade_i$ is equal to:

$$ATT_i \times LEN\ ATT_i + UP_i \times LEN\ UP_i$$

where:

LEN ATT_i is equal to the average length of service for attriters at $paygrade_i$ and LEN UP_i is the average length of service for upgrades at $paygrade_i$

which must be trained per year to replace the individuals lost through attrition and promotion. This algorithm is described in Table 8-11. The actual replacement values, which were determined for each MOS/skill in the SPH predecessor, reference, and conceptual systems, are listed in the course costing sheets in Table C6-3 in Appendix C6.

The algorithm listed in Table 8-11 provides estimates of the number of replacement personnel required for each skill level. Once the general replacement personnel requirements for each skill level have been developed, the exact number of replacement personnel taking the individual courses within these skill levels must be determined. These values are developed by first determining the percentage of total manpower requirements for that skill level who are directly involved in the operation/maintenance of the equipment related to the course. (This percentage is available from data generated during the Manpower Analysis.) This percentage is then multiplied by the total number of replacement personnel at that skill level to provide estimates of the number of replacement personnel who must take a specific course.

Determine Resource Requirements

In this step, the training resources which are required to produce the "steady-state", replacement personnel, are determined. Training resources are estimated only for the system-specific courses. During the initial iteration of the methodology, the only training resource requirements, which are explicitedly examined are the number of instructors associated with the system-specific courses.[12] In the ESPAWS application, the term "system-specific course" is used to refer to (1) the AIT courses for all of the MOSs associated with the predecessor, reference, or conceptual systems, and (2) the advanced service school courses providing specific instruction on SPH-related systems.

Estimation of the number of instructors associated with the system-specific ESPAWS courses was determined by applying a modified version of the instructor determination algorithm listed in the Staffing Guide for U.S. Army Service Schools (DA PAM 570-558). Basically, this algorithm was modified to make total instructor contact hours a direct function of the

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[12] Other course-related resources are implicitly considered in the determination of the individual student cost per course.

number of students taking the course, rather than a function of the frequency of the course. (This frequency is itself a direct function of the number of students taking the course and the optimum class size.)

Appendix C5 provides a detailed listing of the modified instructor determination algorithm and lists the input/output values associated with its SPH applications. One of the major data inputs for this algorithm is the total instructor contact hours associated with each course. The procedures and data sources used in developing the estimates of instructor contact hours for the system-specific SPH courses are also listed in Appendix C5.

Table 8-12 lists the instructor requirements for the SPH predecessor, reference, and conceptual system. At an overall level, the conceptual system will require 161 (or 30 percent) fewer instructors than the predecessor system, while the reference system will require 184 (or 34 percent) fewer instructors.

8.3.3.3 Determine Training Course Costs

Two categories of training-related costs are determined during the initial iteration of the methodolgoy: training course costs and instructor salary costs associated with system-specific courses.

Determine Training Course Costs

Four different types of training course costs are determined:

(1) Individual Student Cost Per Course -- the cost to train an individual in a particular training course.

(2) Average Individual Training Cost -- the average individual training cost provides an estimate of what it would cost to train one individual who completed all of the courses contained in the training path for a particular MOS. It is determined by the following equation

Table 8-12. Instructor Requirements.

MOS	Predecessor	Reference	Conceptual
	Number of Instructor Personnel		
13B	508.3	281.8	316.4
31V	0	14.6	13.4
41C	4.7	4.7	4.7
44B	2.8	2.8	2.7
45D	0	15.9	3.1
45K	17.3	23.3	23.3
45L	6.	11.9	14.2
63B	0	0	0
63C	.9	.9	.9
Totals	540.0	355.9	378.7

$$\sum_{i=1}^{N} CPS_i \times W_i$$

where n is the number of courses in the training path, CPS_i is the Cost Per Student for the ith course, and W_i is the proportion of personnel in the MOS taking that course within the skill level in which the course is located. W_i will generally be 1.0, except for special system-specific courses (e.g., ESPAWS computer course) which are only taken by a portion of the individuals in an MOS.

(3) Replacement Personnel Training Cost -- replacement personnel training cost for each MOS is determined by the following equation:

$$\text{Replacement Cost} = \sum_{i}^{N} (CPS_i \times NREP_i)$$

Where CPS_i is the Cost Per Student for the ith course and $NREP_i$ is the number of replacement personnel taking that course.

(4) Cumulative Personnel Training Cost -- the cumulative personnel training cost for each course provides an estimate of the cumulative training costs associated with each point in the training path. It is determined by the following equation:

$$CPER_i = \left(\sum_{j=1}^{i} CPS_j \ W_j \right) \times NREP_i$$

where $CPER_i$ is the cumulative training cost for the ith course in the training path, CPS_j is the Cost Per Student for the jth course in the career path; W_j is the percentage personnel in the MOS taking the jth course and $NREP_j$ is the number of replacement personnel taking the ith course.

Estimates of the individual student cost per course are determined in one of two ways. First, for existing courses, this cost is taken directly from the MOS Training Cost Handbook. Secondly, for modified or additional courses, the individual cost per student is determined by identifying a comparable existing course, obtaining relevant cost data on the existing course from the MOS Training Cost Handbook, and modifying this cost data to reflect differences between the

course lengths of the existing and projected course. The exact algorithm used in developing the individual student cost per course for the modified/additional courses is listed in Appendix C6 along with actual input and output values associated with these courses.

Once the individual cost per student is determined, the other three cost measures are determined by applying the equations described above. Appendix C6 provides a cost sheet for each MOS associated with the SPH predecessor, reference, and conceptual systems. This sheet lists all of the calculations and input values involved in the determination of the average individual training costs, the replacement personnel training costs, and the cumulative personnel training cost.

Table 8-13 displays the average individual training cost associated with each of the MOSs in the SPH predecessor, reference, and conceptual systems.

Table 8-14 displays the replacement personnel training costs associated with the MOSs from the SPH predecessor, reference, and conceptual systems. The yearly cost of training the replacement personnel associated with the conceptual system will be $23,505,238 (21 percent) less than the predecessor system. The yearly cost of training replacement personnel in the reference system will be $10,702,250 (9 percent) less than the cost of training replacement personnel in the predecessor system.

Determination of Instructor Costs

Table 8-15 lists the instructor salary costs associated with training personnel in the SPH system-specific predecessor, reference, and conceptual training courses.[13] The ESPAWS conceptual system required 161 fewer instructors for the system-specific courses than the predecessor system for a projected annual savings of $1,761,783 (30 percent) in

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[13] Determination of the annual salary figure used in Table 8-15 (E-6 with 8 years experience) was achieved by (1) examining DA PAM 570-558 to determine the typical paygrade requirements for the instructor billet at Army service schools, and (2) examining the average time in grade data, available from the Personnel Analysis, to determine the typical years in service for an E-6.

Table 8-13. Average Individual Training Costs (FY1980$)*

MOS	Predecessor	Reference	Conceptual
13B	27,623	27,617	27,617
31V	21,600	26,003	26,003
41C	55,160	55,160	55,160
44B	26,115	26,115	26,115
45D	–	31,461	31,461
45K	31,297	31,297	31,297
45L	35,410	35,966	35,678
63B	26,611	26,611	26,611
63C	38,147	38,147	38,147

*Multiply by 1.14 to obtain costs in FY1981$.

Table 8-14. Replacement Personnel Training Costs.

MOD	Predecessor	Reference	Conceptual
13B	86,954,622	52,190,075	57,430,401
31V	0	10,226,144	1,403,416
41C	1,310,361	1,310,361	1,310,361
44B	589,850	589,850	589,850
45D	–	10,688,577	2,500,929
45K	6,220,093	8,401,778	8,401,778
45L	1,415,636	3,428,810	3,968,695
63B	228,259	228,259	228,259
63C	1,437,982	1,704,488	1,704,488
Total (1980 dollars)—	98,156,803	88,768,342	77,538,177
Inflation Factor—	x 1.14	x 1.14	x 1.14
Total (1981 dollars)—	111,898,760	101,195,910	88,393,522

Table 8-15. Summary of Instructor Salary Costs (FY1981$)

MOS	Predecessor		Reference		Conceptual	
	Number	Cost*	Number	Cost*	Number	Cost*
13B	508	$5,551,855	281.8	$3,077,932	316.4	$ 3,455,847
31V	0	–	14.6	159,467	13.4	146,360
41C	4	51,335	4.7	51,335	4.7	51,335
44B	2	30,582	2.8	30,582	2.7	29,490
45D	0	–	15.9	173,666	3.1	33,859
45K	17	188,957	23.3	254,491	23.3	254,491
45L	6	65,534	11.9	129,976	14.2	155,098
63B	0		0		0	
63C	.9	9,830	.9	9,830	.9	9,830
Total	540	5,898,095	355.9	3,887,281	378.7	4,136,312

*Salary cost for one instructor is assumed to be equal to yearly salary cost for E-6 with 8 years experience ($10,922.4–FY1981 dollars).

instructor salaries. The reference system required 185 fewer instructors than the predecessor for a projected annual savings of $2,010,814 (34 percent).

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SECTION 9
RESULTS

This section contains a discussion of the results from applying the HARDMAN methodology to the ESPAWS Self-Propelled Howitzer. The first five subsections deal with specific results. Section 9.6 contains the conclusions reached as a result of the study effort. The final section, 9.7, contains recommendations for further study, or for actions which would improve the efficacy of the methodology.

9.1 WORKLOAD

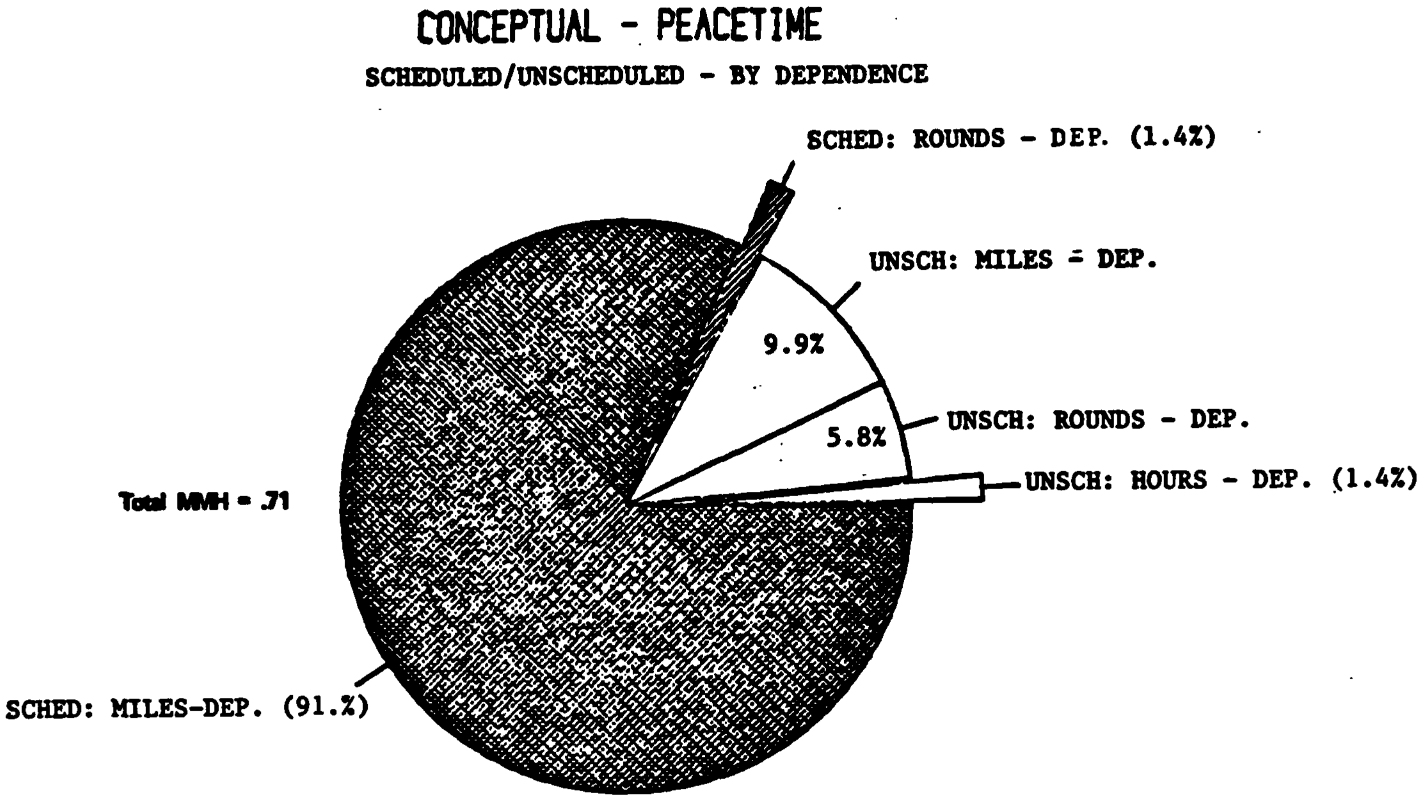
As discussed in Section 6.3.2, there were two basic workload categories covered by the scope of the study: operational and maintenance workload. The derivation of operational manning (OM) workload was discussed in that section and will not be repeated here except to note that OM, i.e., crew, workload requirements follow directly from the development of the Mission Profile/Operational Mode Summary (MP/OMS). Since the MP/OMS is a reflection of a particular scenario assumption, OM workload requirements cannot be presumed to be fixed but rather must vary with different scenarios.

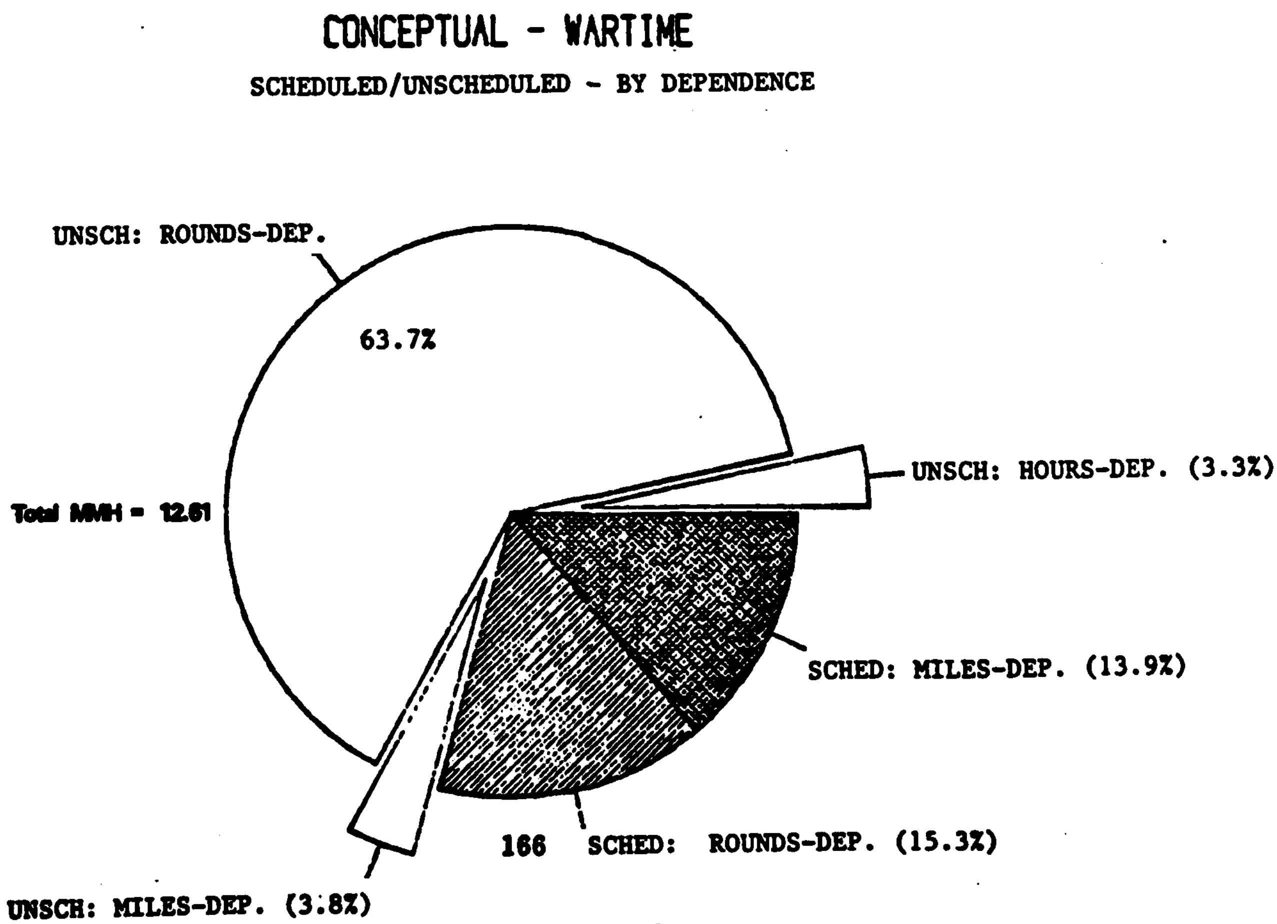
Maintenance workload, i.e., scheduled maintenance (SM), unscheduled maintenance (UM), and preventive maintenance checks and services (PMCS), is different in that it can be a function of design. Apart from providing input to Manpower Requirements Analysis, a principal reason for determining maintenance workload in the HARDMAN methodology is to identify high drivers, i.e., subsystems that cause the largest maintenance workloads. However, it must be noted that this question is also a function of a variable scenario.

Figure 9-1 illustrates this point.[1] The two pie charts depict the ESPAWS conceptual system maintenance workload

1 Preventive maintenance checks and services (PMCS) workload are excluded from this and all subsequent workload comparisons in Section 9.1. This workload is presumed not to be a function of design, but rather of scenario, hence its inclusion would have distorted the comparison.

Figure 9-1. Scenario Comparison.





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(crew and organizational) under both peacetime and wartime conditions. Scheduled maintenance predominates in peacetime, as represented in the top figure. However in combat the number of rounds fired in a typical day increases dramatically (300 vs. a peacetime average of 4); thus unscheduled maintenance on subsystems whose failure rates are a function of rounds fired becomes the "high driver". Scheduled maintenance still accounts for a significant portion of maintenance workload (29% of the total). (Although the size of each chart is the same, as noted they do not represent equal workload.) Thus the question of what constitutes a high driver is shown to be a function of scenario.

Figure 9-2 provides a comparison of different designs within the wartime scenario. The conceptual system experiences a decline in maintenance manhours compared with the reference system. However, it can be seen that the decline occurred in that portion of unscheduled maintenance workload accounted for by subsystems whose failure rates are a function of hours operated. This alerts the analyst to revaluate the design differences between the reference and conceptual systems that occur in hour-dependent subsystems. In this case, the decline in workload can be traced to the incorporation of the AN/AYK-14 computer and the KHS-2100 Land Navigation System in the conceptual system design, both of which have very high estimates of reliability. It is also noted from Figure 9-3 that scheduled maintenance consumes a significant proportion of maintenance resources in all three design concepts.

Figure 9-4 further identifies the particular subsystems responsible for the greatest contribution to unscheduled maintenance workload, under wartime conditions. Again there are workload decreases between the reference and conceptual systems, this time identified to the Cab and Fire Control subsystems. These changes are also due to the incorporation of the subsystems mentioned in the previous paragraph. As can be seen, refining the analysis to this level allows identification of high drivers, in this case the Cab, Armaments, and Electrical subsystems for all three designs. These subsystems remained high drivers of maintenance workload because of the design assumption made in Section 5, i.e., to incorporate the predecessor system equipments completely into the notional designs, so as to provide a manual backup capability for those functions which

FIGURE 9-2. WARTIME DAILY MAINTENANCE MANHOURS

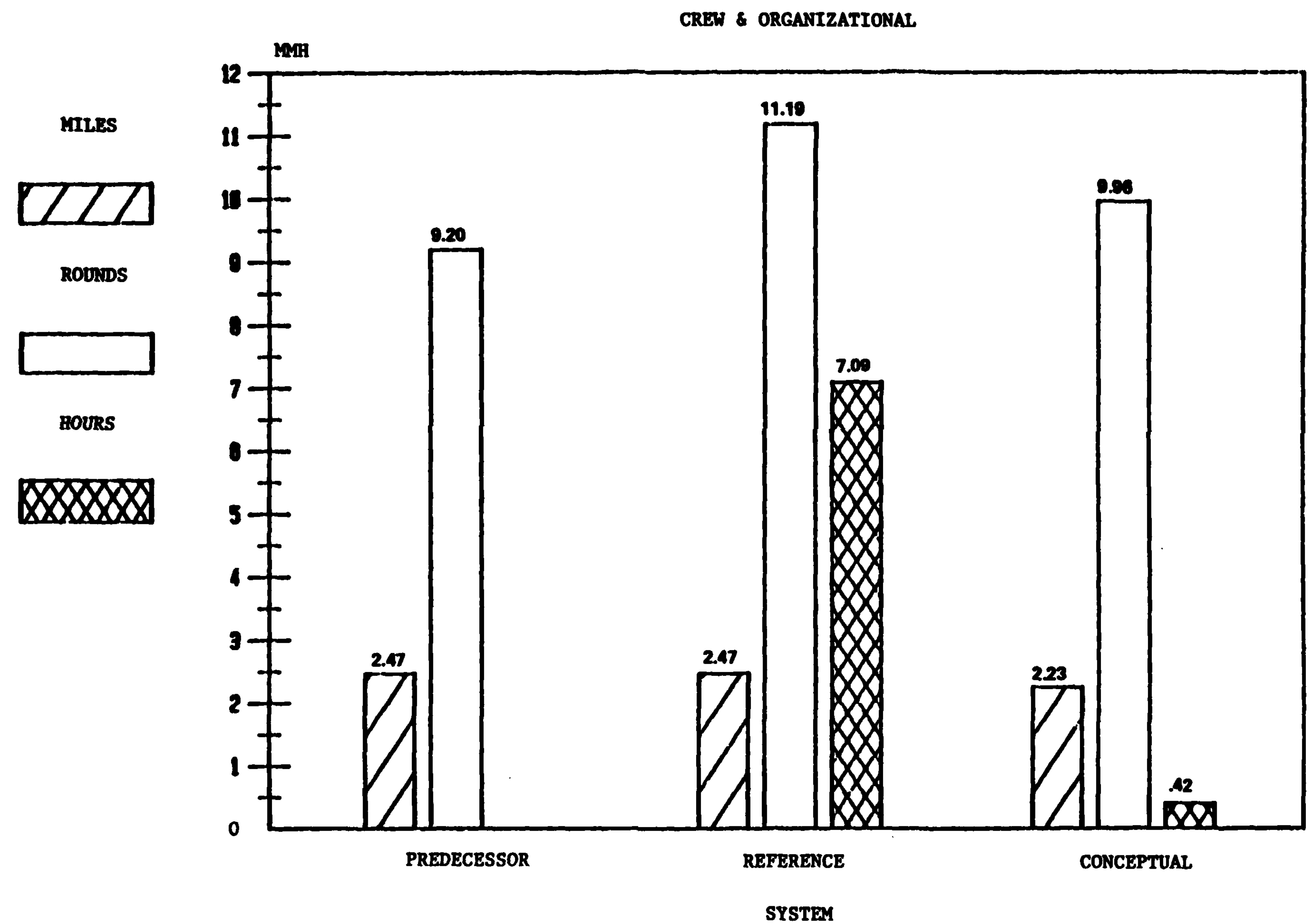


FIGURE 9-3. WARTIME MAINTENANCE WORKLOAD DISTRIBUTION

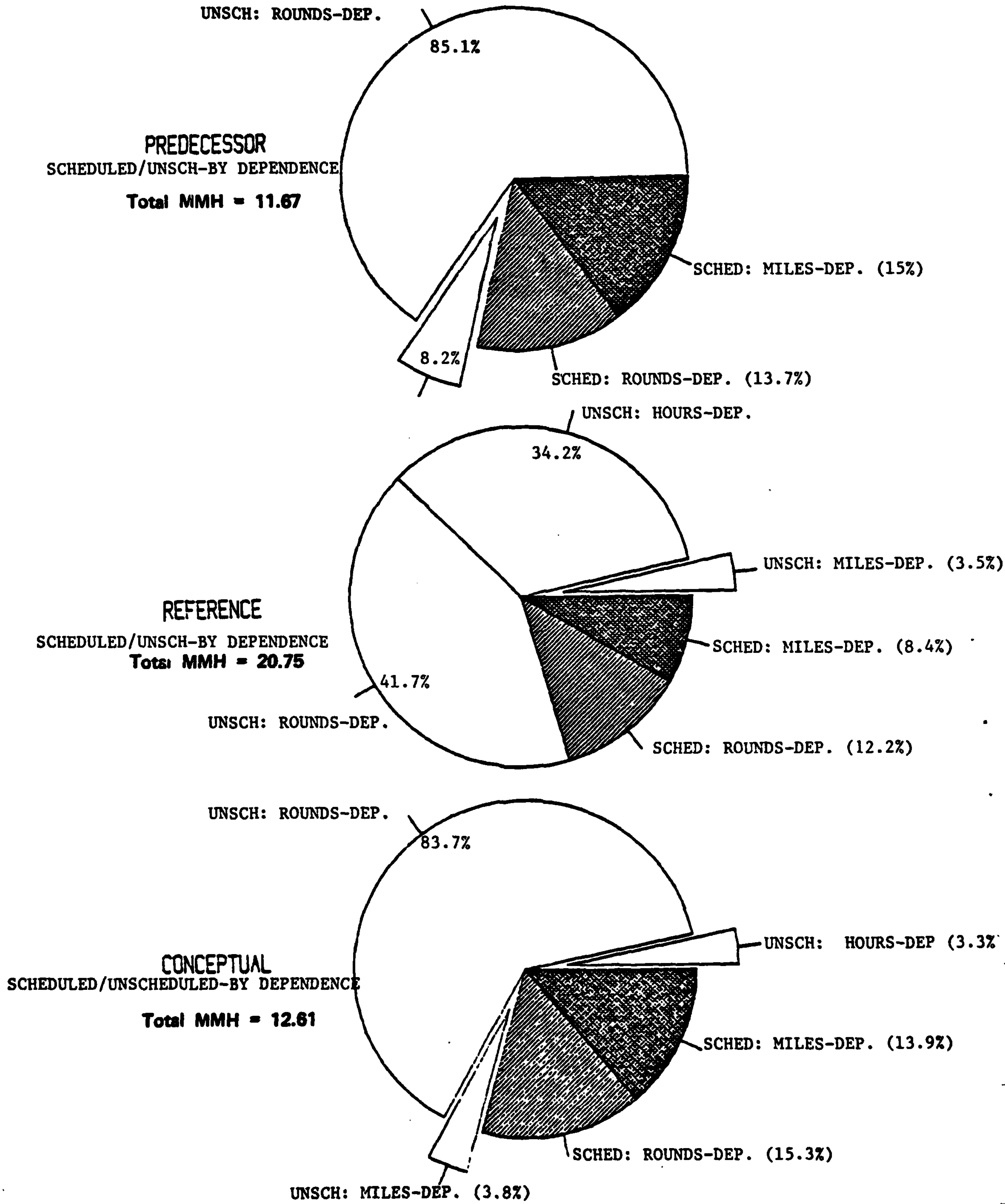
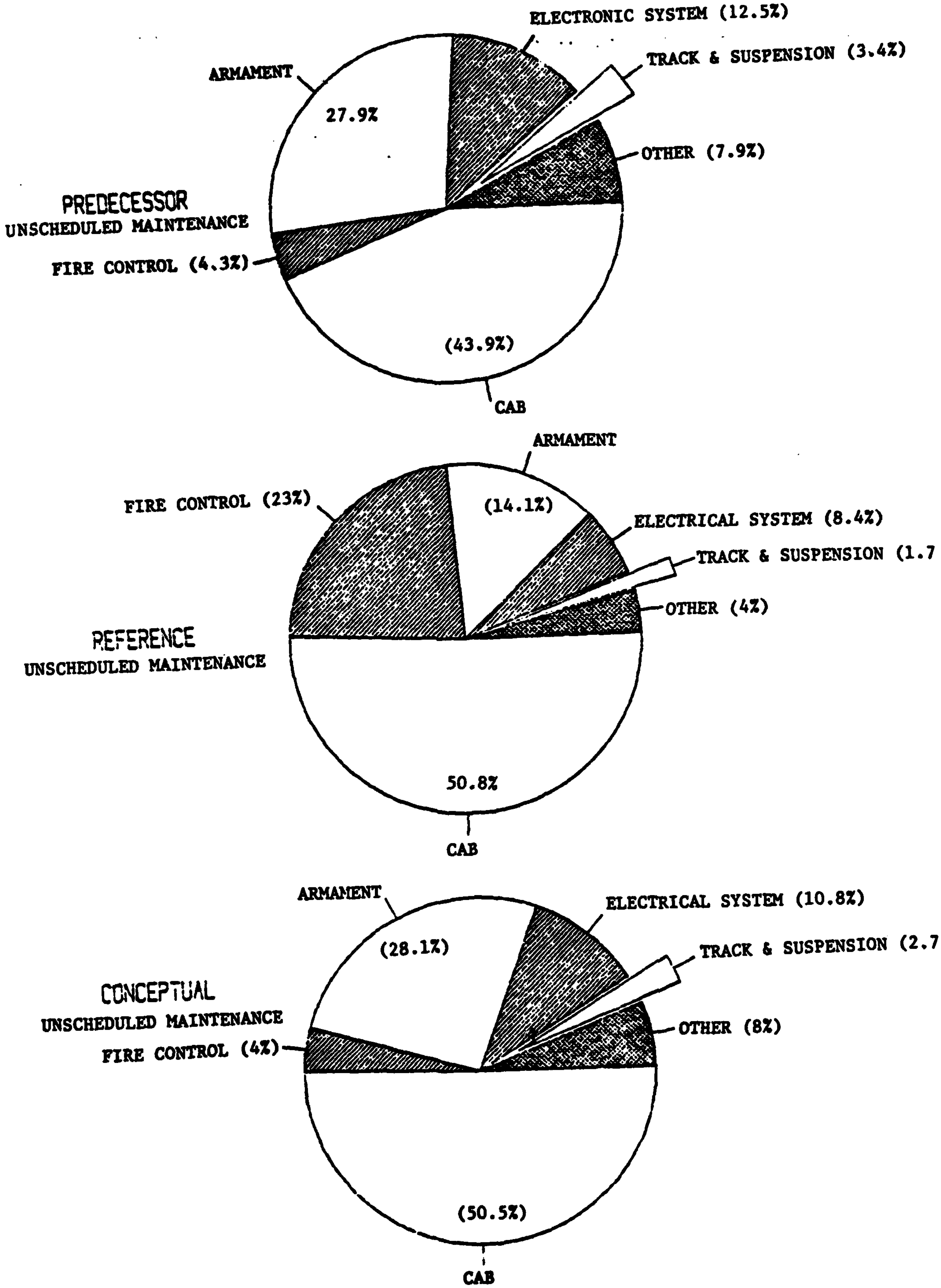


FIGURE 9-4. WARTIME UNSCHEDULED MAINTENANCE DISTRIBUTION



were automated. Thus, had some of these equipments been eliminated, maintenace workload would have decreased.

9.2 AVAILABILITY

Inherent availability (A_i) was determined for the predecessor, reference, and conceptual systems. This availability is the aggregate of all the inherent availability values calculated by the AVLBYGG report program for all of the subsystems that comprise each configuration. A_i for each subsystem was obtained from the equation

$$A_i = \frac{MTBF}{MTBF + MTTR}$$

where

MTBF = Mean Time Between Failure: rate of occurrence for all unscheduled maintenance events. Failures that were round or miles dependent were normalized to hours.

MTTR = Mean Time To Repair: the average Active Maintenance Time (AMT) required to complete maintenance actions at all echelons of maintenance. In most cases, time could not be identified exclusively to one maintenance echelon, necessitating the included AMT from all echelons.

The "inherent" availability denotes a capability driven by the design characteristics of the equipment. Table 9-1 presents the inherent availability values associated with the main functional groupings of the ESPAWS reference and conceptual designs, and the predecessor M109A1. The aggregate values are presented below.

	A_i	Δ%
Predecessor	.70930	-
Reference	.47811	- 32.6% compared to the predecessor
Conceptual	.70194	+ 46.8% compared to reference - 1.0% compared to predecessor

Table 9-1 INHERENT AVAILABILITY

GG No.	Subsystem	Predecessor	Reference	Conceptual	Conceptual System Change
01	Engine	.99454	.99454	.99835	Improved RAM
03	Fuel	.99725	.99725	.99767	Improved RAM
04	Exhaust	.99983	.99983	.99983	
05	Cooling	.99628	.99628	.99713	Improved RAM
06	Electrical	.95814	.95814	.96138	Improved RAM
07	Transmission	.99754	.99754	.99754	
08	Transfer/Final Drives	.99912	.99912	.99912	
11	Rear Axle	.99992	.99992	.99992	
12	Brakes	.99971	.99971	.99971	
13	Track and Suspension	.99420	.99420	.99484	Improved RAM
14	Steering Controls	.99990	.99990	.99990	
16	Shock Absorbers	.99986	.99986	.99986	
18	Hull	.99999	.99999	.99999	
19xx	Existing Cab Equipment	.85655	.85655	.85655	
1920	Land Navigation	–	.86521	.99984	KHS-2100
1925	FM Radio	–	.98264	.98264	
1930	Autoloader	–	.96175	.99837	Modular design, BITE
20	Spade	.99513	.99513	.99513	
22	Hull Miscellaneous	.99993	.99993	.99993	
26	Special Tools	.99676	.99676	.99676	
28xx	Existing Fire Control Equipment	.97598	.97598	.97598	
2810	Fire Control Computer	–	.82437	.99561	AN/AYK-14
34	Armament	.91904	.91904	.91904	
43	Hydraulic	.99314	.99314	.99314	
47	Weighing and Measuring	.99993	.99993	.99993	
76	Fire Extinguisher	.99994	.99994	.99994	
95	Standard Parts	.99998	.99998	.99998	
	TOTAL	.70930	.47811	.70194	

Several design changes, and an underlying assumption, were responsible for the changes in overall availability, and the large variances between the predecessor, reference, and conceptual system availability values. The significant contributors to availability differences were:

The underlying design assumption to retain the predecessor system equipments as part of the reference and conceptual systems lowered availability. Three of the largest contibutors to low availability were existing cab equipment (19XX), existing fire control equipment (28XX), and the armaments group (34). No improvements were made to these subsystems. Had the decision been made to replace some of this predecessor equipment, rather than to retain it as manual backup, A_i would have been higher for both the reference and conceptual systems.

The land navigation system (1920) availability improved significantly between the reference and conceptual systems. This was the result of a reliability value estimate from a contractor which may be optimistic. This estimated value may require validation through prototyping/breadboarding, given the subsystem's significance in the total system A_i.

A similar situation exists for the fire control computer (1925). What field data exist on the AN/AYK-14 indicates that it has very high reliability and, hence, high availability. As more data become available, due to the widespread deployment of the AN/AYK-14, this value may decrease.

The Autoloader (1930) exhibited a modest improvement in reliability due to evolutionary improvements in technology, such as modular design and BITE.

Design changes for improving the RAM characteristics of several automotive subsystems (engine-01, fuel-03, cooling-05, electrical-06, and track and suspension-13) resulted in only slight improvements in availability in the conceptual system. This occurred because the improvements to MTBF and/ or MTTR, as a result of design changes, were overshadowed by the large

MTBF and MTTR values associated with induced maintenance actions, which were not affected by design changes. (A recent GAO report estimated that over 50 percent of all equipment failures were human induced.)[2]

9.3 MANPOWER

The primary purpose of this study in the area of manpower requirements was to determine the feasibility of utilizing the generic HARDMAN Manpower Requirements Analysis to develop manpower requirements for an emerging Army weapons system in its conceptual phase. The manpower requirement estimations resulting from this application appeared to be reasonably accurate, given the available data.

Several "firsts" were achieved in this successful feasibility test. Among the most significant were the determination of operator workload data utilizing a general projected mission environment; the application of a primarily maintainer oriented manpower methodology to this operating workload; and the incorporation of MACRIT as a foundation for Army HARDMAN Manpower Requirements Analysis. Additionally, the successful normalization of non-Army workload data and subsequent use in determining manpower requirements further substantiates the distinct advantages of multi-service capabilities and data bases. In order to clearly present the results of the Manpower Requirements Analysis, a comparision and explanation of any differences in manpower requirements between systems considered in this study was necessary.

Prior to this comparison, however, it was necessary to develop predecessor manpower requirements based on only that workload (maintenance and operator) which was within the scope of this study. Further, to provide a valid comparison, consistent methodology was used, in this case, as outlined in Sections 6.3.3 and 6.3.4. This comparison among three systems is thus a comparison between the manpower requirements of an existing system, a notional

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2 "Effectiveness of U.S. Forces Can Be Increased Through Improved Weapon System Design", GAO Report Number PSAD-81-17, January, 1981.

system of existing equipments, and a notional system of equipments which incorporate low risk technological improvements. In this way the full impact of design differences on manpower requirements can be examined. The predecessor manpower requirements are shown in Tables 9-2 and 9-3.

Figure 9-5 displays the crew level manpower requirements for 1960 howitzers (the projected ESPAWS procurement quantity) in each of the three systems. There is only one required MOS, 13B, and each system's total and individual paygrade requirements are shown. The difference in manpower requirements between predecessor and conceptual/reference system results from the high degree of automation present in the conceptual/reference systems. This is reflected in the capability to perform a primary fire task being present in the manpower set of five that is available to perform the operator/maintainer workload.

This same capability is not present in the predecessor operator/maintainer manpower set. While both operator and maintainer workload is less, ARI's Howitzer Crew Size Model dictates a minimum of seven operating stations. This number in turn sets the minimum crew manpower at seven, which was in accordance with the constraints of having a continuous primary fire task capability present at all times. The apparent "no difference" between reference and conceptual system is somewhat misleading. Improvements projected for the conceptual system leave approximately 17 hours per week per crew available for additional work as opposed to the six hours per week available in the reference system.

The transition from the predecessor system to the highly sophisticated and automated new system is accompanied by a decrease in crew manpower requirements. This decrease occurred even though the capabilities of the conceptual system are significantly greater than those of the predecesssor system. The expected increase in maintenance manhours occurred in the transition from predecessor to reference due to equipment additions. However, projected technological improvements caused an actual decrease in maintenance manhours for the conceptual system. In both cases, reference and conceptual, some maintenance manhours could be absorbed by the positions needed to fulfill operational workload requirements. One additional maintenance position was needed in both cases, however. The conceptual system's crew manning was then operator/ maintainer "driven." This was not the case in the predecessor system in which the "drivers" were the primary fire tasks. The identification of these "drivers" was

Table 9-2. Predecessor System Crew Manpower Requirements.

Title	MOS	Paygrade
Chief of Section	13B30	E6
Gunner	13B20	E5
Assistant Gunner	13B10	E4
Cannoneer 1	13B10	E4
Cannoneer 2	13B10	E3
Cannoneer 3	13B10	E3
Cannoneer 4	13B10	E3

Table 9-3. Predecessor System Unit Manpower Requirements.

	Number	Skill	Level
	1	13B	E7
	1	63B	E6
	1	63C	E6
	3	45K	E5
	1	45L	E5
	1	63C	E5
	1	13B	E4
	1	41C	E4
	4	45K	E4
	1	44B	E4
	2	45L	E4
	1	63C	E4
	1	45K	E3
Total	19		

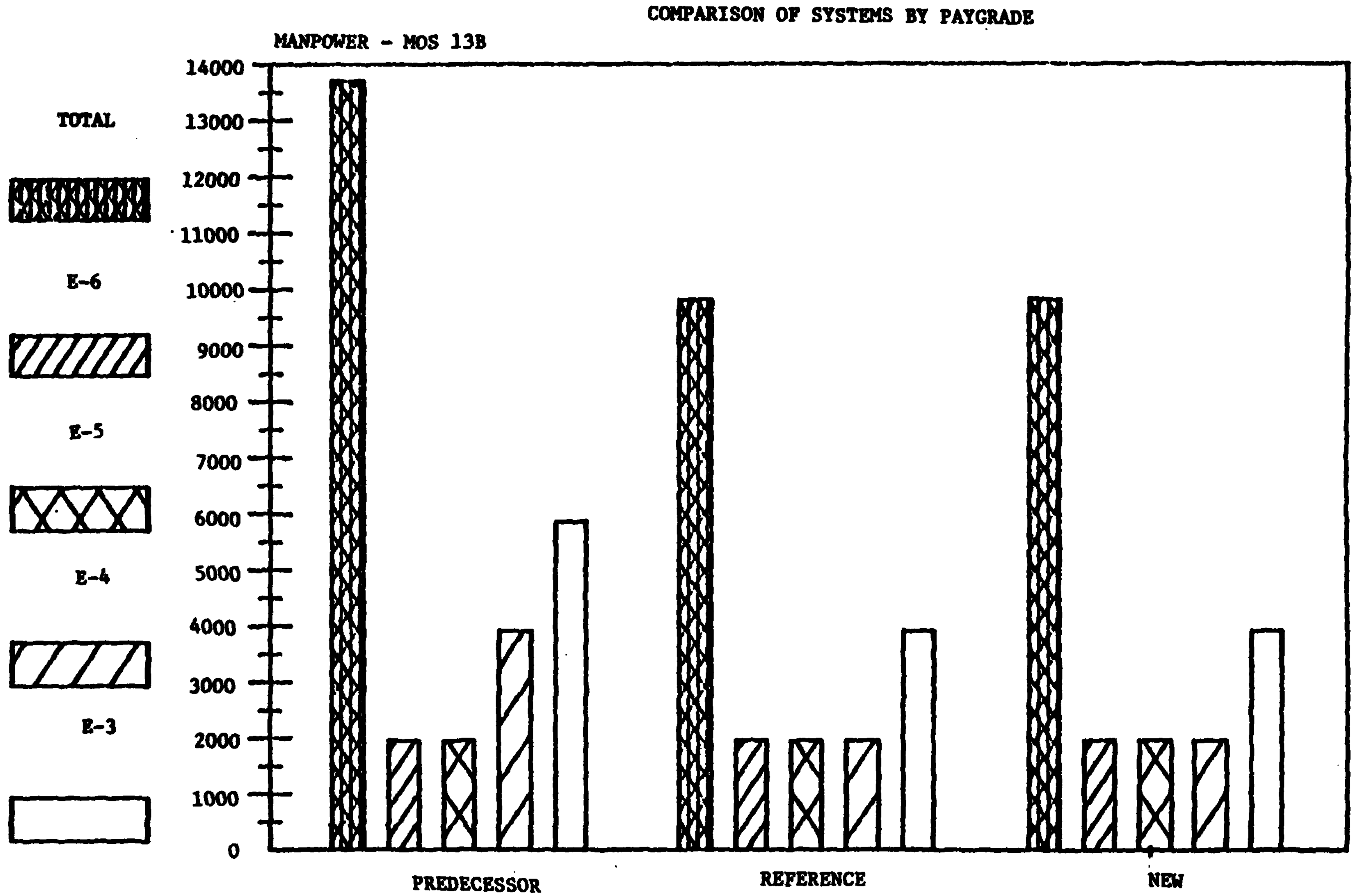
BY PAYGRADE

E7	E6	E5	E4	E3	Total
1	2	5	10	1	19

BY MOS

	13B	41C	44B	45K	45L	63B	63C
E7	1	0	0	0	0	0	0
E6	0	0	0	0	0	1	1
E5	0	0	0	3	1	0	1
E4	1	1	1	4	2	0	1
E3	0	0	0	1	0	0	0
Total	2	1	1	8	3	1	3

FIGURE 9-5. CREW MANPOWER REQUIREMENTS (AGGREGATE)



important as it leads to the identification of metrics, which can be utilized to develop manpower requirement algorithms. These algorithms can then be used to drive accurate manpower requirements. This method is both time and cost efficient in that only a sample of selected sites, units, or crews must be subjected to a complete and detailed workload survey. Equally as important as metrics to this method is the establishment and maintenance of audit trails through task/event networks. Equipment changes during the life cycle of a system often change the high driver and metric. If a clear and concise audit trail containing well maintained workload data is available, the associated algorithm can be corrected without the expense in time and money of detailed on-site surveys.

Figures 9-6 and 9-7 display the organizatión maintenance manpower requirements for the predecessor, reference, and conceptual systems. Two figures were necessary in order to clearly display the comparisons among the three systems due to the large differences in MOS 31V requirements. Additionally, to provide another means of comparison, the densities of the predecessor system were normalized to 24 weapons per unit. This is represented by the dotted line. The increase in 13B requirements between predecessor and reference system was due to the addition of the autoloader. MOS 41C, 44B, and 63B manpower requirements in all three systems are predicated on a small (less than five hours per week, per unit) workload that requires tasks uniquely associated with these MOSs, and further study in this area could prove beneficial. If, for example, these tasks were within the stated capabilities of a 31V, a savings of 243 in the total manpower requirements is possible.

MOS 45K and 63C both display increases in manpower requirements between the predecessor and new systems. These increases are due to changes in weapon density, 24 vs. 18, as can be seen from the dotted line which represents normalized weapons density.

The increase in MOS 45L requirements in the reference system resulted from the addition of an autoloader. It is significant that, while technological improvements in the conceptual system did decrease 45L workload, the decrease was not sufficient to decrease the "whole position" manpower requirements of 45L in the conceptual system. The possibility exists here to examine the feasibility of moving enough 45L workload to another maintenance echelon and take advantage of the technological improvements in the autoloader to lower overall 45L manpower requirements.

FIGURE 9-6. ORG. MANPOWER REQUIREMENTS (AGGREGATE)

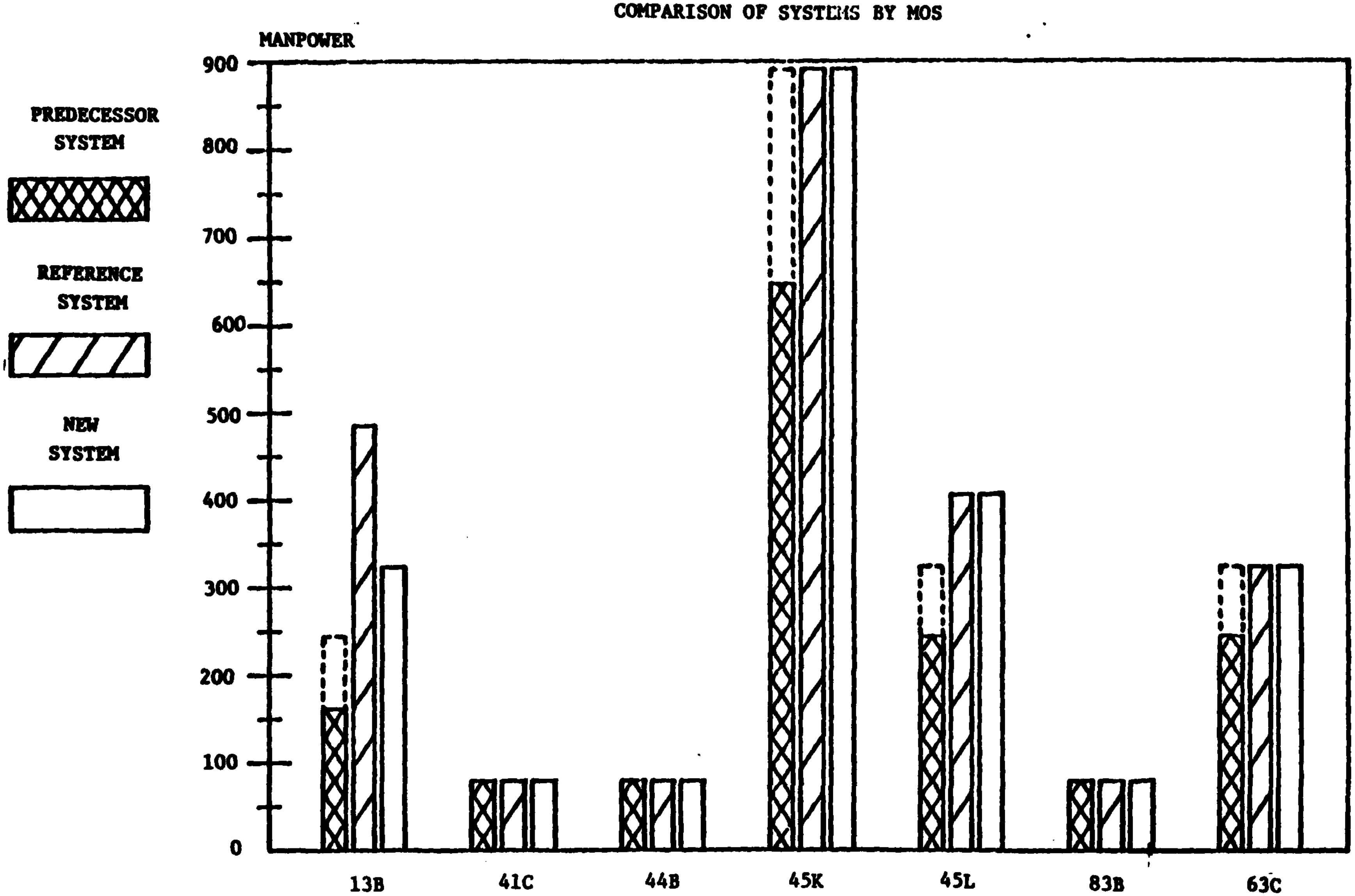
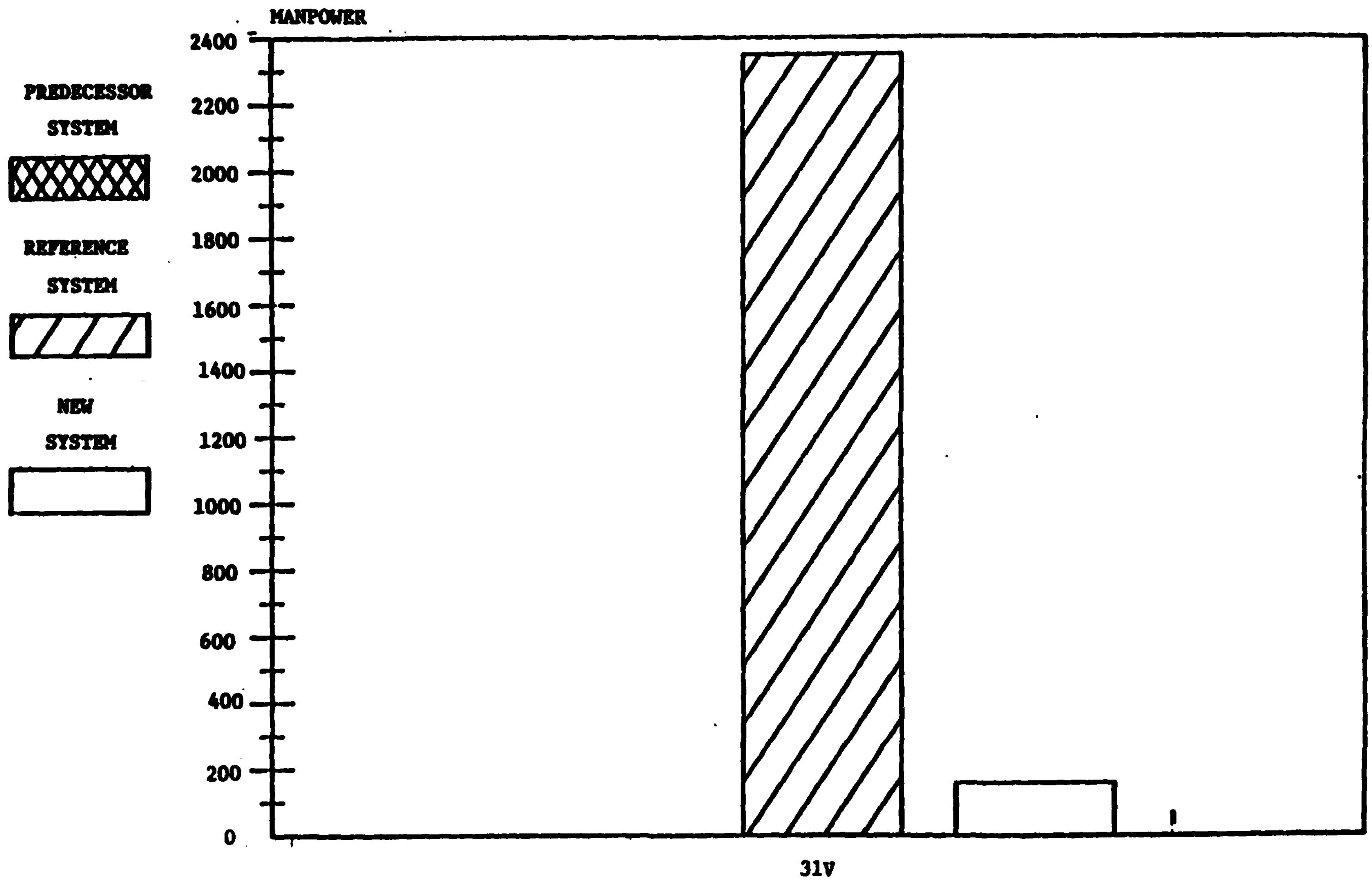


FIGURE 9-7. ORG. MANPOWER REQUIREMENTS (AGGREGATE)

MOS 31V - COMPARISON OF SYSTEMS



As can be seen in Figure 9-7, the changes in MOS 31V manpower requirements are significant. The addition of an Attitude and Heading Reference System (AHARS), a computer and a radio to the reference system all created significant workload, which required the skills of MOS 31V. It must be remembered that these requirements did not exist in the predecessor system, hence, the zero manpower requirement. The decrease in MOS 31V manpower requirements that occurs in the conceptual system was based on contractor estimates of technological improvements and associated reduced maintenance and improved reliability for both the land navigation and computer system. While the results of a reliability test of a similar computer to that envisioned for ESPAWS tend to bear out the estimated decrease in computer maintenance, this large a design difference impact does require further evaluation before it can be substantiated. It is important to note, however, that the methodology was successful in identifying this high driver for further investigation.

In summary, the application of the HARDMAN Manpower Requirements Analysis to ESPAWS demonstrated the feasibility and value of the methodology in developing manpower requirement for a conceptual Army system. The methodology was capable of utilizing multi-service data and building on a foundation of approved Army manpower requirement drivers and metrics.

9.4 PERSONNEL RESULTS

The parameter of importance in analyzing personnel requirements for the purpose of HARDMAN is to look at the differential values which are produced by increasing or decreasing the manpower requirements of a system. In this way, a relative comparison is made between two systems. It should be stressed that the values produced by the Minimum Flow Solution model are not intended to be used by personnel managers, as they are optimistic due to the assumption that all manpower requirements are to be met. In addition, the personnel values are derived as if all manpower requirements must be initially filled and then sustained, disregarding the fact that there is a currently existing population which may be used. The reason for this is twofold:

(1) Since requirements are system-specific, the relative number of individuals who may be assigned to the conceptual system is unknown, and

(2) The assumption that the initial fill rate must be established provides a basis for equal comparison of two systems.

Therefore, comparisons were made to determine the relative demand between the predecessor and conceptual systems, and between the reference and conceptual systems. Comparisons were made at the MOS level, as well as the aggregated (system) level. Table 9-4 depicts the relative increases/decreases by MOS. The overall conceptual system requires 7.6% less personnel than the predecessor system, and 15.7% less than the reference system.

For the predecessor-conceptual comparison, note that this differential is substantially driven by the MOS 13B (Cannon Crewmember), since the requirements for the howitzer crews drop significantly. (There were 13,608 crew members required for the predecessor system, and 9720 for the reference and conceptual systems.) Excluding 13B, the aggregated differential amounts to an increase of 26.5% for the conceptual system over the predecessor.

For the reference-conceptual comparison, the large drop in the MOS 31V (Tactical Communications Systems Operator/ Mechanic) requirement from 2349 to 162 produced the large overall decrease in the conceptual system requirements, although each MOS experienced a decline or remained the same (See Table 9-4). (Figure 9-8 is a graphic display of the comparisons.)

The values produced by this analysis would be compared to personnel inventory projections during the Impact Analysis Step, in order to identify potential tradeoff areas.

Another area of interest in the Personnel Analysis is an examination of the outputs produced from the step which establishes the personnel pipeline flow characteristics. Since the data were separated by groupings of AFQT categories within MOS, the factors associated with each AFQT category can be examined and compared. Further, the percentages of AFQT distribution can be interactively altered to examine the effect of changes in this area. Other parameters are also perturbable; this is discussed in Appendix B4 and examples are presented in Appendix B5.

Table 9-4. Relative Differentials in Total Personnel Requirements.

MOS	Conceptual Over Predecessor	Conceptual Over Reference
13B	–14.4%	–1.8%
31V	no predecessor value	–96.3%
41C	0%	0%
44B	0%	0%
45K	+33.3%	0%
45L	+31.2%	–14.6%
63B	0%	0%
63C	+40.9%	0%

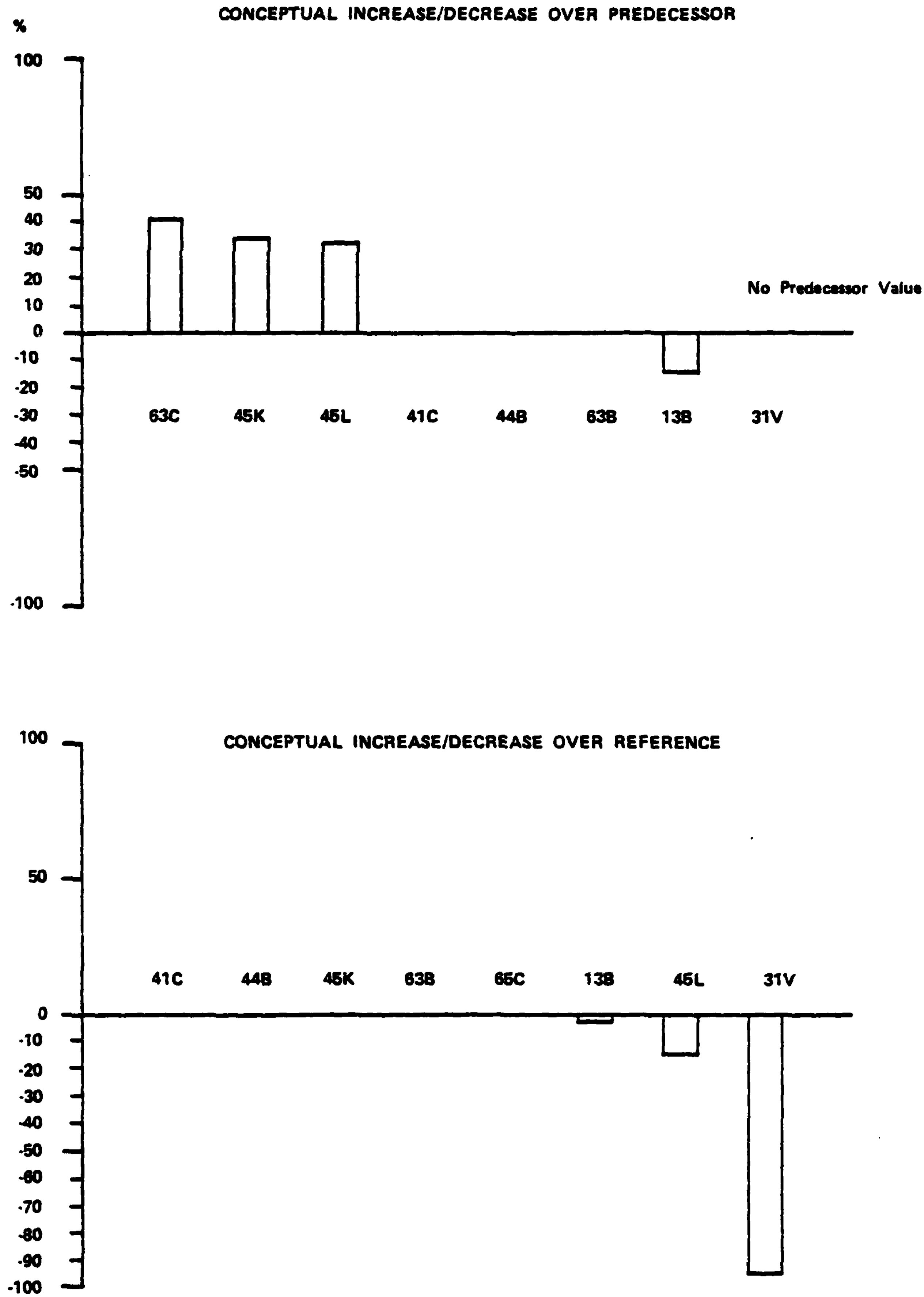


Figure 9-8. Predecessor/Conceptual and Reference/Conceptual Comparisons.

9.5 TRAINING RESULTS

Training results are presented in four areas: (1) task-related impacts, (2) training course curriculum impacts, (3) instructor requirements and their associated salary costs, and (4) training course costs.

9.5.1 Task -- Impacts

Table 9-5 displays the deletions and modifications made to existing tasks and the additional tasks which were required for the SPH reference and conceptual systems. As Table 9-5 indicates, the greatest reference system impacts were related to the 13B, 31V, 45L, and 45D MOSs. The conceptual system had relatively minor task-related impacts, over and above the reference system impacts. The only types of task changes/additions related to the conceptual system were changes in task frequency for thirteen tasks in the 13B 63C, 45L, and 45K MOSs. These changes in task frequency were required to reflect the changes in reliability associated with the conceptual system design differences.

9.5.2 Training Course Curriculum Impacts.

Two existing courses (041-13B10 -- Field Artillery Crewman, and 643-45D10 -- Field Artillery Turret Mechanic) were modified to reflect the task changes required for the SPH reference system. In addition to these modified courses, requirements for three additional courses were specified (642-ASIX1 -- ESPAWS Autoloader, 101-ASIX2 -- ESPAWS Land Navigation System, and 101-ASIX1 ESPAWS -- Computer).

Because of the relatively small task impacts associated with the conceptual design differences, no changes in the modified/additional reference courses were required for the conceptual system.

Table 9-5. Summary of Task-Related Impacts.

MOS	REFERENCE AUT.	REFERENCE MIN.	REFERENCE REL.	REFERENCE MAJ.	REFERENCE ADD.	CONCEPTUAL AUT.	CONCEPTUAL MIN.	CONCEPTUAL REL.	CONCEPTUAL MAJ.	CONCEPTUAL ADD.
13B	2	46	22	16	4	0	0	3	0	0
(45D)*	–	–	–	–	6	–	–	–	–	0
31V	0	0	0	0	13	0	0	0	0	0
41C	0	0	11	0	0	0	0	0	0	0
44B	0	0	0	0	0	0	0	0	0	0
45K	0	10	0	0	0	0	0	1	0	0
45L	0	18	0	0	10	0	0	3	0	0
63B	0	0	0	0	0	0	0	0	0	0
63C	0	9	0	0	0	0	0	6	0	0
Total	2	83	33	16	33	0	0	13	0	0

Task Deletion	AUT. – Automation Task Deletion
Task Modification	MIN. – Minor Task Modification Required
	REL. – Change in Task Frequency; Otherwise Task Essentially the Same
	MAJ. – Major Task Modification Required
Task Addition	ADD. – New, Additional Task Required

*Complete task listing for 45D not yet available.

9.5.3 Instructor Requirements

The SPH conceptual system will require 161 fewer instructors than the predecessor system for a projected yearly salary savings of $1,761,783 (30 percent) in instructor salaries. The ESPAWS reference system will require 185 fewer instructors for the system-specific courses for a projected year savings of $2,010,814 (34 percent).

9.5.4 Training Course Costs

Table 9-6 displays the replacement personnel training cost associated with the SPH predecessor, reference, and conceptual systems. The yearly cost of training the replacement personnel associated with the conceptual system will be $23,505,238 (21 percent) less than the predecessor system. The yearly cost of training replacement personnel in the reference system will be $10,702,250 (9 percent) less than the cost of training replacement personnel in the predecessor system.

Thus, while the cost of training a single individual increased (See Table 8-13) in the reference and conceptual systems courses, this increase was offset by large reductions in the number of replacement personnel who had to be trained in these systems. Hence, an overall reduction in yearly replacement personnel training costs was achieved.

9.6 CONCLUSIONS

This study had one purpose: to test the feasibility of using the HARDMAN methodology to determine the human resource implications of emerging Army weapon systems. To accomplish this, the following objectives were established:

> Determine the availability of the quantity and quality of data required by the HARDMAN methodology.
>
> Determine the utility, for Army application, of the analytic tools developed for other service applications. This meant developing new tools as required.

Table 9-6. Summary of Training Course Costs (FY1981 $).

	Predecessor	Reference	Conceptual
REPLACEMENT PERSONNEL TRAINING COST	$111,898,760	$101,195,910	$88,393,522

Adapt, when necessary, both the data and analytic tools to the policy and procedural requirements of the Army's acquisition and development processes.

Demonstrate the methodology by applying its first four steps to a major Army weapon system.

The results from demonstrating the methodology are presented in Sections 9.1 through 9.5. These results support a general conclusion that the methodology is feasible for application to Army systems. Specific conclusions subordinate to the general conclusions, and limitations or these are presented in the following subsections. These subsections are organized according to the other objectives of the study -- Data, Analytic Tools, and Policy.

9.6.1 Data

Data were required in sufficient quantity and quality to support the application of the HARDMAN methodology. The overall availability of data was sufficient to support this initial iteration of the HARDMAN methodology. Cost data, in particular, were readily available from a variety of sources. However, dependence on data via formal letters of request, sometimes resulted in (a) inordinate delays in the receipt of requested data, (b) failure of the addressee to deliver requested data, and (c) the delivery of incomplete, inapplicable, and sometimes incorrect data thereby instigating delays while the request is repeated. This was particularly true in the case of the data requested from the Enlisted Master File, and to a lesser extent for other data requests. It was concluded that these problems, while not unusual, were symptomatic of others, organizational problems associated with the conduct of effective front end analysis (see 9.6.3, below).

Other potential problems related to data availability are as follows:

Predecessor field maintenance data were obtained from the Field Artillery Sample Data Collection (SDC) System. However, the SDC does not cover all systems (see Appendix A2). A firm conclusion about the generalizability of the methodology must

await other application efforts using data other than that of the SDC.

Consolidated Occupational Data Analysis Program (CODAP) data were not received, although requested. These data were not crucial to the analysis but would have improved the quality of the analysis.

Systematic data bases, formats or listings, or single sources were not available for several types of data related to training analyses. These data were Programs Of Instruction (POIs), Soldiers' and Commanders' manuals, instructor contact hour information, and the skills and knowledge associated with required tasks. Data had to be collected from a multitude of sources, thus increasing time and the risk of delay.

A representative Mission Profile/Operational Mode Summary, in the form prescribed by the RAM Rationale Annex Handbook, was not available for most of the study. This information was crucial to the conduct of the analysis because it was necessary to determine workload (see Section 9.1). An MP/OMS was not received until very late in the study effort.

The overall quality of the data received was generally excellent. The SDC data, in particular, were better in some respects than field maintenance data collected by other service maintenance data collection systems. Cost data also were very greatly detailed, and internally consistent, apparently due to a strong emphasis in the Army on rigorous cost analysis. However, there were some problems noted:

Although the SDC data contained the MOS, paygrade, and manhours of maintenance personnel associated with a particular maintenance incident, these were haphazardly identified to maintenance echelons. This could be changed by redesigning the form used to collect the data.

The Non-Commissioned Officer Education System and Advanced Individual Training Graduation Date fields on the Enlisted Master File tapes were virtually blank. This prevented the construction

of career paths which are normally part of the Personnel Requirements Analysis.

There was great variation in the task designations listed in the Soldiers' and Commanders' manuals, both in terms of the types of task action verbs used and in the level of specificity. Maintenance tasks as recorded did not follow the generally employed taxonomy contained in the maintenance manuals. (The methodology could be greatly facilitated if a standardized task taxonomy was used.)

There were discrepancies between the task numbers and titles listed in the soldiers' and commanders' manuals and the objectives listed in the Program Of Instruction (POIs).

POIs often do not systematically describe the media associated with various course modules.

9.6.2 Analytic Tools

The ability to adapt existing analytic tools for the application of HARDMAN to ESPAWS was largely dependent on their data input requirements and how closely their internal logic mirrored the particular circumstances of the Army. The R&M portion of the Reliability, Maintainability, and Cost Model (RMCM) was found not to be appropriate because it could not satisfy these two criteria (see Appendix B1). Only the general conceptual logic of the model appeared applicable.

On the other hand the Minimum Flow Solution Model seemed to be adaptable for the ESPAWS application. Because of the gaps on educational history from the EMF data, an alternative routine was developed to track personnel categories by AFQT score (see Section 9.4). Other tools were developed to overcome the misallocation of maintenance personnel to echelons (see Appendix A2.5) and to perform the same workload calculations as RMCM (see Appendix B1). If broader applications of the methodology are to be undertaken, however, improved analytic tools must be developed. These would include, but not be limited to, a better method for consistent description of the functional elements of design (the system found for ESPAWS was not consistent); quantitatively-based standard algorithms for

assigning tasks to training locations and to media types; estimating relationships for determining the cost and resources of training which occurs in unit settings; and a more detailed, integrated methodology for determining manpower requirements. (This last area is the object of a review effort for the current method, MACRIT.)

Additionally, mention must be made of the Howitzer Crew Size Model developed by the ARI Field Unit at Fort Sill, Oklahoma. While programming difficulties prevented DRC from employing this model as developed, it was extremely useful in assessing combat operational workload, as a result of its detailed taxonomy of mission tasks. While the present model appears to be too system specific to be widely used, it represents an important first step in the systematic modeling of combat operational workload, one that with appropriate revisions can perhaps be directly used to provide operator requirements for other systems.

9.6.3 Policy

Only one general conclusion was drawn with respect to the policy and procedural aspects of the weapon system acquisition process (WSAP) in the Army. It appeared that the responsibility for the execution of system analysis in the early phases of the WSAP was very fragmented. It was concluded that this fragmentation was chiefly responsible for the lack of coordination and delays in the receipt of data essential to the conduct of the study. (The delay in receiving a representative Mission Profile/Operational Mode Summary provides a good example.) This fragmentation of responsibility has been recognized by the Army[3] and efforts are underway to correct it. It is significant in the context of this report because the fragmented responsibility inhibits the broader application of detailed front-end analysis of the human resource implications of design, which this study was designed to demonstrate.

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3 Blanchard, G.S., and Kerwin, W., "Man/Machine Interface -- A Growing Crisis", Army Top Problem Areas Discussion Paper Number 2, August 1980.

9.7 RECOMMENDATIONS

There are three general recommendations:

- The principal qualification to the conclusions presented above is that the methodology was only applied to one hardware system. Therefore, it is recommended that efforts to apply the HARDMAN methodology be expanded to a broader range of systems. These systems should include the ESPAWS SPH, and its associated support vehicles, to take advantage of the Consolidated Data Base established as part of this study effort. Other warfare areas should also be considered for pilot applications, such as command, control, communications and intelligence (C^3I) systems, logistics support platforms, ground combat and combat support vehicles, and aviation systems.

- New data bases must be established, and existing data bases should be expanded, integrated, and reorganized to effectively support front-end analysis. (A similar recommendation was made by a recent GAO report.)[4] Future data collection efforts on hardware systems, such as the Sample Data Collection, should be coordinated with the results of Mission Area Analyses (MAA). In this way the requirements for new systems emerging from MAA, which result in a MENS, will trigger data collection efforts (if no data exists) so that meaningful front-end analyses (such as applications of the HARDMAN methodology) can be conducted during the conceptual phase of system development. Lack of appropriate data would severely inhibit these efforts. Further, the ability to target only those systems of interest for which data are necessary would preclude excessive data collection efforts, and thus conserve funds. Existing training and cost data bases should also be integrated into single,

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4 "Effectiveness of U.S. Forces Can Be Increased Through Improved Weapon System Design", GAO Report Number PSAD-81-17, January 1981.

systematic data bases so that front-end analysis may be facilitated.

- New analytic tools must be developed, and existing tools improved. The work begun in this study can serve as a good foundation for improvements in existing analytic tools. More work is needed, especially in developing a comprehensive manpower requirements determination model, and in the modeling of operational workload. Other analytic tools are required, especially new training algorithms, design functional element descriptive methods, and standard task taxonomies. Efforts to develop these must be initiated, if meaningful front-end analysis, as represented by this and future applications of the HARDMAN methodology, is to become a reality in the Army.

GLOSSARY OF ACRONYMS

AFHRL	Air Force Human Resources Laboratory
AFMCO	Air Force Modernization Coordination Office
AFQT	Armed Forces Qualification Test
AHRS	Attitude and Heading Reference System
AIT	Advanced Individual Training
AMST	Advanced Medium STOL Transport
AMT	Active Maintenance Time
AR	Army Regulation
BDP	Battlefield Development Plan
BITE	Built-In Test Equipment
BOIP	Basis of Issue Plan
CDB	Consolidated Data Base
CHRT	Coordinated Human Resource Technology
CMF	Career Management Field
CNO	Chief of Naval Operations
DA PAM	Department of the Army Pamphlet
DCP	Decision Coordinating Paper
DCSPER	Deputy Chief of Staff for Personnel
DIF	Difficulty-Importance-Frequency
DLSIE	Defense Logistic Studies Information Exchange
DMDC	Defense Manpower Documentation Center
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DODT	Design Option Decision Tree
DoN	Department of the Navy
DSWS	Division Support Weapon System
DTIC	Defense Technical Information Center
EIC	Equipment Identification Code
EMF	Enlisted Master File

ESPAWS	Enhanced Self-Propelled Artillery Weapon System
ETM	Extension Training Material
GAO	Government Accounting Office
GG	Government Functional Group Code
IFV/CFV	Infantry Fighting Vehicle/Cavalry Fighting Vehicle
IOC	Initial Operational Capability
IPS	Integrated Program Summary
ISD	Instruction System Development
JGD	Job Guide Development
KP	Kitchen Police
LSA	Logistics Support Analysis
MAA	Missions Area Analysis
MACRIT	Manpower Authorization Criteria
MDCS	Maintenance Data Collection System
MEEI	Minimum Essential Elements of Information
MENS	Mission Element Need Statement
MFS	Minimum Flow Solution
MMBF	Mean Miles Between Failure
MMH	Maintenance Manhours
MMM	Maintenance Manpower Modeling
MOS	Military Occupational Specialty
MP/OMS	Mission Profile/Operational Mode Summary
MPT	Manpower, Personnel, and Training
MRBF	Mean Rounds Between Failure
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
NATO	North Atlantic Treaty Organization
NCO	Non-Commissioned Officer
NEC	Naval Enlisted Classification
NERAC	New England Research Application Center
NETP	New Equipment Training Plan
NTIS	National Technical Information Service
OICTP	Outline Individual and Collective Training Plan

OJT	On-the-Job Training
OM	Operational Manning
OMB	Office of Management and Budget
PMCS	Preventive Maintenance Checks and Services
PMOS	Primary Military Occupational Specialty
PM TRADE	Project Manager Training Devices
POI	Program of Instruction
QQPRI	Quantitative and Qualitative Personnel Requirements Information
RAM	Reliability, Availability, and Maintainability
R&D	Research and Development
R&M	Reliability and Maintainability
RMCM	Reliability, Maintainability, and Cost Model
SDC	Sample Data Collection
SM	Scheduled Maintenance
SOC	System Ownership Cost
SPA	Skill Performance Aid
SPH	Self-Propelled Howitzer
SSN	Social Security Number
STOL	Short Take-off and Landing
TOE	Table of Organization and Equipment
TRADOC	Army Training and Doctrine Command
TRRA	Training Resource Requirements Analysis
UIC	Unit Identification Code
UM	Unscheduled Maintenance
WSAP	Weapon System Acquisition Process
WUC	Work Unit Code

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